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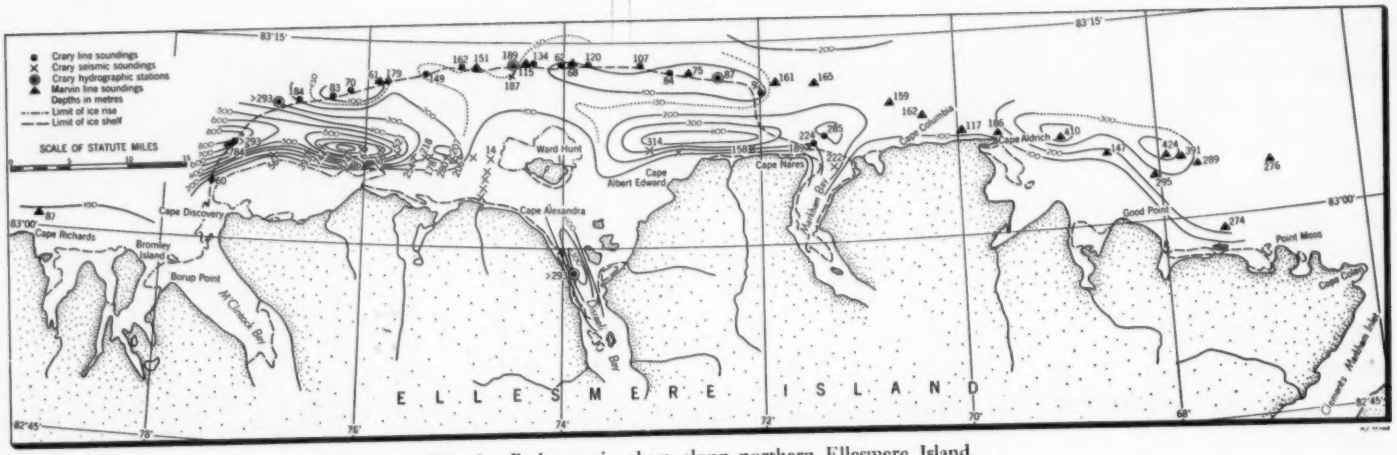

Fig. 1. Bathymetric chart along northern Ellesmere Island.

GEOPHYSICAL STUDIES ALONG NORTHERN ELLESMERE ISLAND

A. P. Crary*

Part I. Bathymetry

WATER depths in the general area of Ward Hunt Island off the north coast of Ellesmere Island, extending east to Point Moss and west to the mouth of M'Clintock Bay, were obtained from three general sources: line soundings made by Ross G. Marvin of the Peary Expedition of 1906; line soundings made by G. Hattersley-Smith and the author in 1954; and seismic observations made through the ice shelf by the author in the same summer.

In the summer of 1906, when Peary left on his memorable trip westward along the northern shore of Ellesmere Island, he instructed Marvin to take soundings in the polar sea north from Cape Hecla. Marvin, finding the open lead offshore a permanent fixture, was unable to carry out these instructions and proceeded instead along the edge of the smooth bay ice as far as Cape Richards, taking in all twenty soundings. Bushnell (1956) has located Marvin's report of his trip and presented it as it was given to Peary. Marvin's locations were fixed by horizontal angles to prominent capes and peaks, and also by a few sun shots. The latter, however, have not been located, but recent aerial mapping of the northern Ellesmere coast has made it possible to locate the positions from the horizontal angles.

In the last two weeks of June 1954 Hattersley-Smith (1955) and the author also journeyed along this same ice front between Markham and M'Clintock bays, making nineteen soundings, three hydrographic stations, and taking thirteen Phleger bottom core samples. Unfortunately, Marvin's account was not located in time to be of use in the planning or execution of the 1954 programme.

In the late summer of 1954 a total of twenty-five seismic soundings was attempted through the ice shelf, of which nineteen were successful. A portable Southwestern Industrial Electronics Company six-trace portable seismograph was used, with a seventy-five metre spread of geophones. Elastic impulses were produced either by a blow on a piton driven into the ice, or with a small TNT charge located in one of the small drainage ponds that were common on top of the ridges during this period.

Most of these seismic depths were taken along an east-west line extending from Ward Hunt Island west to the ice rise north of Cape Discovery. Five seismic stations were made early in September east of Ward Hunt Island, and

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four more were made in a north-south line connecting the western side of the Ward Hunt ice rise to the Ellesmere mainland. Only two seismic stations were made in the vicinity of line soundings: one due north of Ward Hunt Island, where duplication was good; the other on the new part of the ice shelf north of Cape Nares where thirty-five metres difference in depth was found in about one kilometre. Unfortunately, the records from the north-south line from the Ward Hunt ice rise to the mainland were very poor and showed no definite reflections. By mid-September the air temperatures were dropping rapidly, causing almost constant cracking of the ice due to thermal stresses in the surface. Explosive charges and hammer impulses, both of which were used to some extent in this seismic work, seemed to augment or trigger these ice tremors. Though no definite depths were obtained here, there were no deep reflections noted such as were found along the western line. Additional evidence was obtained well inside Disraeli Bay, where a hydrographic station was made late in September. No bottom was reached here with the three hundred metres of hydrographic cable available.

Fig. 1 shows the bathymetric chart of this general area. It will be noted that a great deal of freedom has been taken in the drawing of the contours. The scarcity of data combined with the great variation in depth would allow other interpretations. This map has been contoured generally with the major deep and shoal features paralleling the coast line.

Hattersley-Smith (1955) has pointed out that extensive glaciation at one time enveloped much of this coast. Erratics were found on Ward Hunt Island at heights of more than 300 metres above sea level. Also, the raised beaches occurring at elevations of forty metres or more, both on Ward Hunt Island and on Ellesmere Island proper, testify to isostatic rise of the land, presumably following the retreat of heavy glaciation which at one time extended from the land into the coastal waters. The interpretation of the bathymetric map is that the shoals that lie 15 to 20 kilometres from the coast are moraines formed by these glaciers. Though the contouring shown would appear to limit these morainal banks to the north, there is no evidence for this.

Following the building up of these moraines, during a time of retreating glaciers, currents may have scoured out the deeps both to the east and west of Ward Hunt Island and to the north of Good Point. Deviation of these waters coastwise would have been caused by the moraines toward the north. Christie (in press) has mapped a late Palaeozoic unconformity in this area along which the deep scouring may have developed.

As seen on the map, there were two adjacent stations north of Cape Discovery, where bottom was not reached by the three-hundred-metre hydrographic line. A thankful acknowledgment must be made to the efforts of Marvin who, in a like situation, sledged back to a cache north of Ward Hunt Island to gather more sounding line and finally obtained a depth of 784 metres. This checks well with the 874 metres found by seismic means under the shelf area farther to the east.

From the seismic observations calculations of the depth of water, of the dip of the ocean bottom, and of the sub-bottom reflections can be made. Some

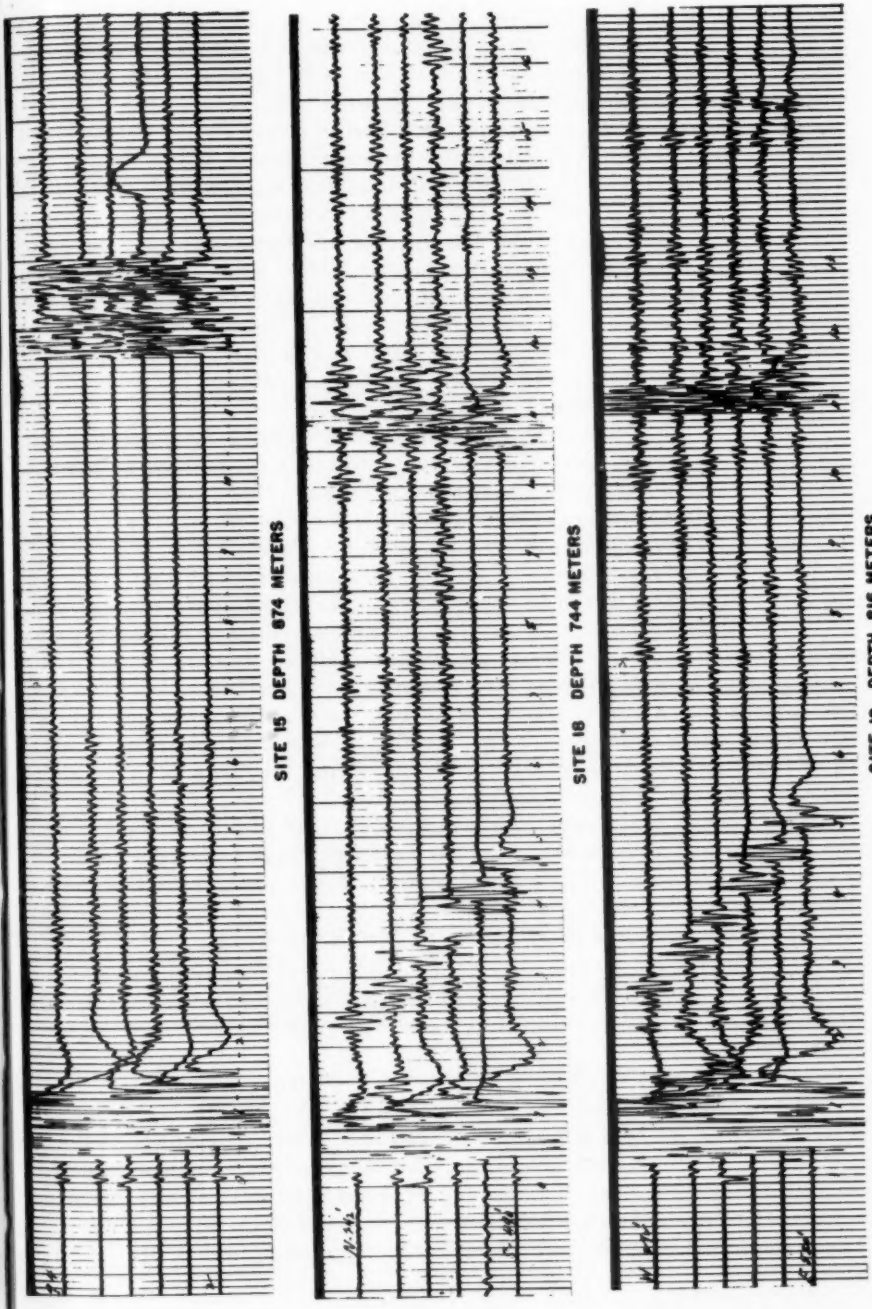

Fig. 2. Seismic records showing bottom and sub-bottom reflections.

general information on the thickness of the underlying sedimentary formations is derived from the depths, where abundant reflection energy is returned. Fig. 2 shows the best examples. These are records taken near the deepest water found under the western part of the shelf. Fig. 3 shows the section along this seismic line that, as can be seen from the map Fig. 1, lies almost parallel to the general strike of the beds. At seismic site 18, where the depth is 744 metres, strike and dip data were obtained that showed a dip of about 20° toward the north-northeast. This indicates that the deepest part of the trough lies somewhat north of the line and that this deepest part may not be continuous with the deep that Marvin located farther west. East of Ward Hunt Island dips in only the north-south direction were obtained. Nearest Ward Hunt Island at a depth of 314 metres the dip was 8.5° to the north; between Cape Albert Edward and Cape Nares at a depth of 158 metres the dip was 24° to the north. Obviously, this feature can not be accurately mapped without further data.

It is to be noted that the waters surrounding southern Ellesmere Island and Baffin Island show many similar off-shore deeps, such as those in Jones Sound, and those in Hudson Strait described by Dunbar (1951). The off-shore Ellesmere moraines have their counterparts also in the banks off western Greenland, although there no deeps lie between the banks and the coast. This may be due to the less rapid retreat of glaciers toward the central Greenland ice cap as compared with that in northern Ellesmere, or to the harder material.

There seems to be little doubt that the bays of northern Ellesmere are typical fiord types even though quantitative evidence is lacking. At the oceanographic station in Disraeli Bay bottom was not reached at 300 metres, although the station was 15 kilometres in from the mouth and less than one-fifth of the width from shore. The presence of islands southeast of Ward Hunt Island and the lack of deep reflections to the southwest of it would indicate a sill near the mouth of the bay.

No soundings were taken in Markham Bay. One seismic sounding and two line lowerings at the mouth of the bay indicated depths below 200 metres, though Marvin's values, a few kilometres north of this, were all less than 200 metres.

To the east, and depending entirely on Marvin's soundings, another deep has been indicated that extends from a point near Cape Aldrich east to a point north of Point Moss. The location of this deep is based on very limited data and its inferred structure is shown as of the same general character as those to the west.

Part II. Hydrographic Stations

The hydrographic stations belong to two periods: three were obtained prior to the summer melt at points north of Cape Discovery, north of Ward Hunt Island, and north-northwest of Markham Bay, whereas three others were obtained during the summer months. In Figs. 4 and 5 the pre-summer salinities and temperatures are shown, together with the values obtained at the ice island T-3 in April 1954, when it was about 300 kilometres northeast of Ward Hunt Island.

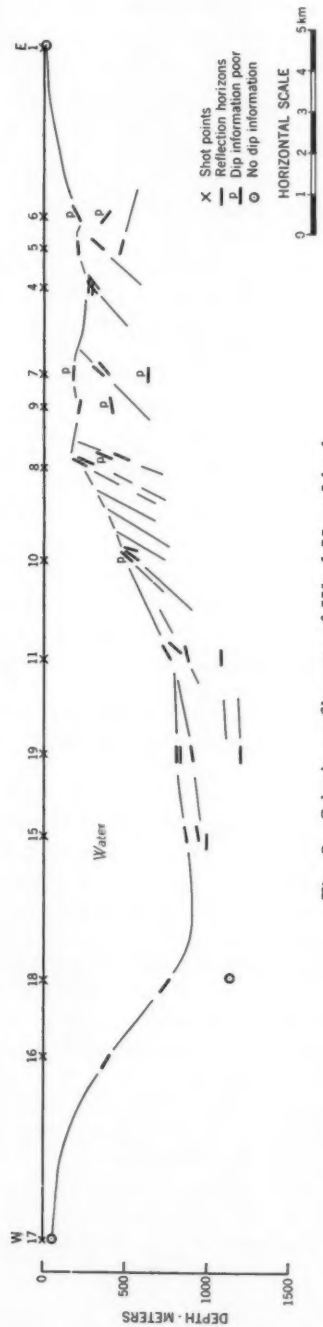

Fig. 3. Seismic profile west of Ward Hunt Island.

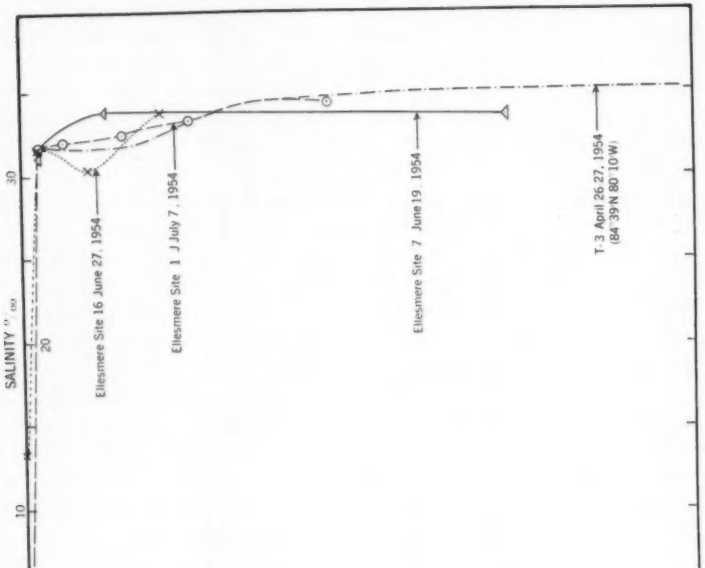

Fig. 5. Salinity measurements before summer melt compared with those from T-3 in April 1954.

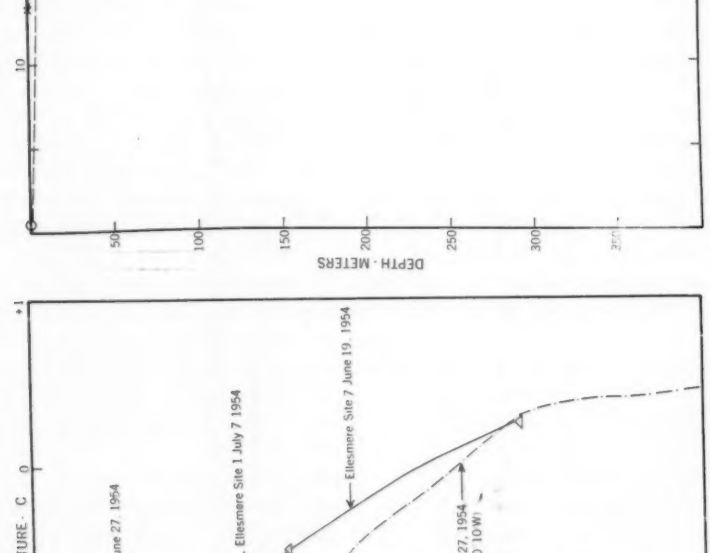

Fig. 4. Water temperatures before summer melt compared with those from T-3 in April 1954.

It will be seen that the temperatures in the first fifty metres are nearly identical with those from T-3. Below fifty metres the temperatures are as much as 0.5°C higher, approaching the T-3 temperatures again at the greater depths. Temperatures taken at T-3 were also higher than those obtained elsewhere in the regions of the arctic basin. These Ellesmere waters are probably heated by fresh waters overlying them in bays and ice shelf areas.

Surface salinities are also high, 31.6 to 31.8‰, in the off-shore waters. High surface salinities, as pointed out by Worthington (1953), may be the result of proximity to the Atlantic water inflow, or, according to Nansen (1902), the result of distance from fresh water river outflows. Both factors undoubtedly affect different arctic areas in varying degrees. It is believed that the amount of open water in the winter season has most likely a large influence on the surface salinity. It is well known that in an area about 80 kilometres wide along the coasts of northern Ellesmere Island and Greenland continuous hummocking and forming of open leads take place that result during the winter months in a steady production of new ice. This process increases the salinity of the remaining waters. In contrast to the seas off northern Alaska and Siberia, the surface water is not freshened by extensive melting or by large river outflows in the summer.

Figures 6 and 7 show the variations of temperature and salinity of the waters during the summer season. These figures were all taken at the station north of Ward Hunt Island, with the exception of those obtained at the station inside Disraeli Bay on September 18. It will be seen that thaw waters are not evident even in early August. The significance of comparing the thaw water characteristics at the station north of Ward Hunt Island at the end of the summer season with waters at the same depths in mid-June is destroyed by the fact that large differences have been observed in the length of the summer season. On T-3 the summer was extremely short in 1953, lasting only from early July to the last week in July, as compared with the summer of 1954 on the Ellesmere ice shelf that extended from early July until early September.

The hydrographic station deep in Disraeli Bay is especially interesting in that it shows that little mixing of fresh and salt water has taken place. Since water at temperatures between 0°C and 4°C is heavier than water at 0°C, and since drainage waters from nearby areas of Ellesmere probably reach little more than 4°C before entering the bay, stratification such as is shown must be the case. The colder salt water will cool the warm bottom layers of fresh water, which then rise by convection until the whole fresh water column is at 0°C. Hence, we should expect minimum summer ablation from the bottom of the shelf, at least in the bays and in areas nearest the coast. Freezing may well take place at both top and bottom of the fresh water column, with the ice formed at the bottom floating upward to unite with that accreting at the under side of the ice shelf. It is extremely unfortunate that an attempt to penetrate Disraeli Bay in early May to establish a hydrographic station before the thaw began, met with failure due to the inability of the dog team to travel through the deep snow encountered inside the mouth of the bay.

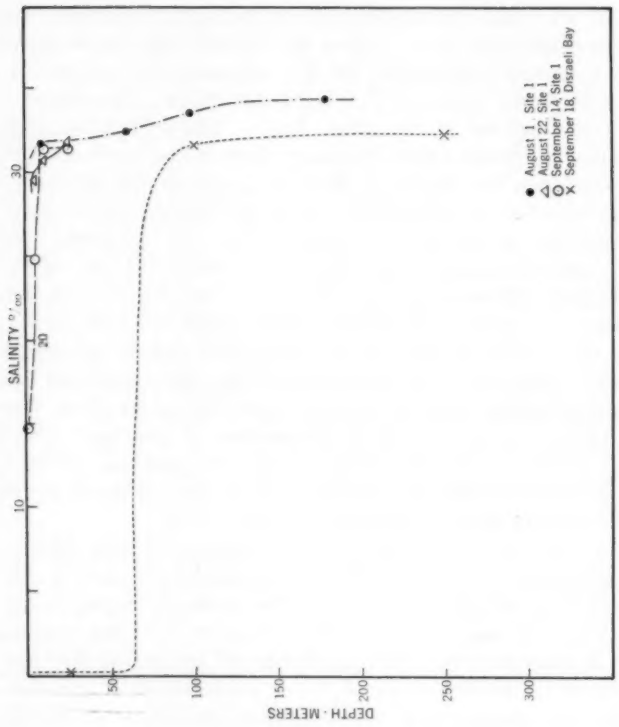

Fig. 7. Variation of salinity during the summer season.

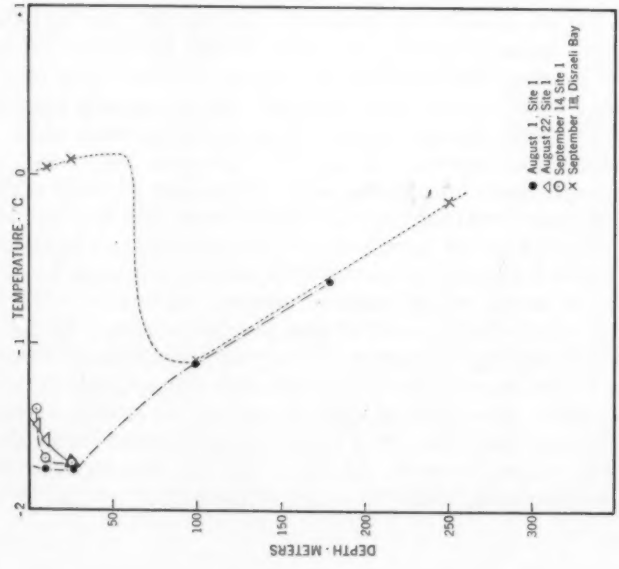

Fig. 6. Variation of water temperatures during the summer season.

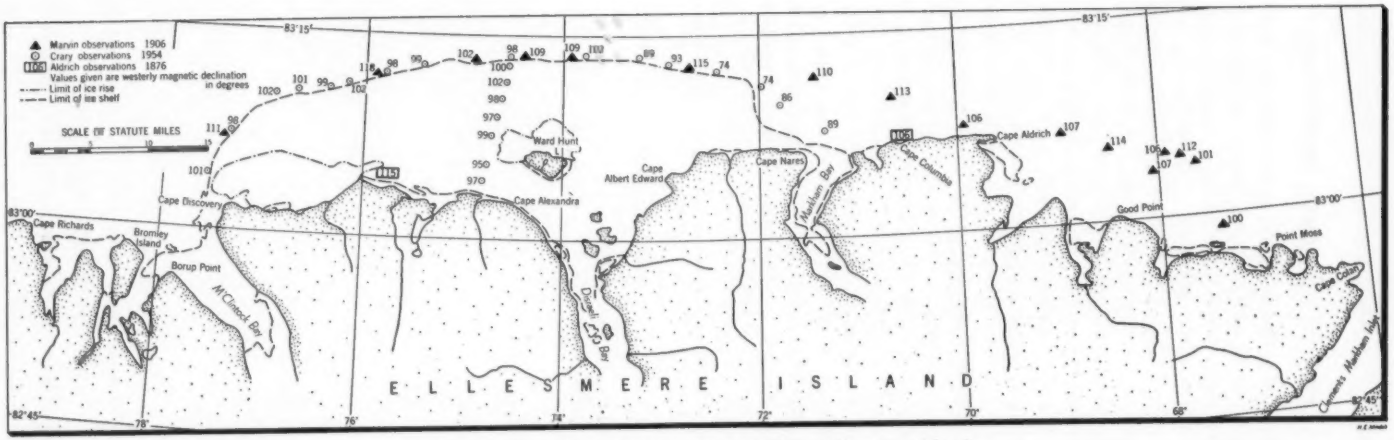

Fig. 8. Magnetic variations along northern Ellesmere Island.

Part III. Magnetic Declinations

Along the line of the transit survey across the width of the ice shelf and along the ice front during the oceanographic studies, magnetic bearings to the mountain peaks were regularly obtained. Marvin took similar magnetic bearings during his trip along the shelf. Reduction to magnetic declination or variation is possible when the locations of the sites of observations are known. The results of these reductions are shown in Fig. 8. It can be seen that in all cases the west declinations obtained from Marvin's data are greater than those obtained in 1954. Two values of declination obtained by Aldrich, who made a trip along the inside of the shelf in 1876, are also shown, but these are not located sufficiently close to later stations to allow direct comparison.

In Fig. 9 are plotted the observations obtained in 1906 and 1954 along the ice front that, as noted previously, had not changed significantly in position in this forty-eight year period. The average value of westerly declination obtained by Marvin is greater by 13° than that found in 1954. Madill (1948) has discussed the historical variations in the location of the North Magnetic Pole. Amundsen made a series of observations in 1904–5 showing the Magnetic Pole to be in the vicinity of 70°30′N and 95°30′W, whereas Madill's value in 1947 was 73°N and 100°W, corresponding to a shift toward the west as viewed from Ward Hunt Island of 9° that agrees quite well with the 13° cited above.

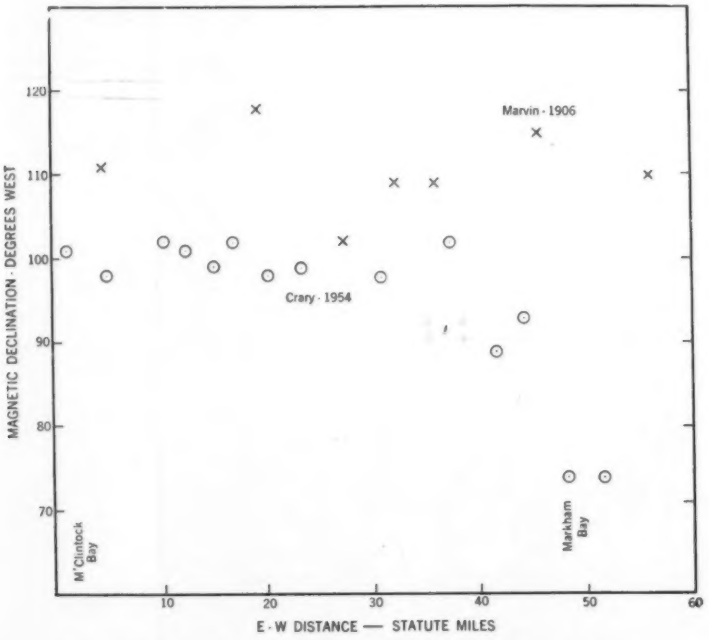

Fig. 9. Comparison of magnetic variations in 1906 and 1954.

Acknowledgments

Acknowledgments are due Geoffrey Hattersley-Smith and R. L. Christie for assistance in field operations and in discussions of results. The graphs and charts, as well as most of the reductions of data were made by Vivian Bushnell of the Air Force Cambridge Research Center.

The oceanographic instruments were obtained from the Woods Hole Oceanographic Institution, to which grateful acknowledgments are given. The determinations of salinity and temperature from samples and field data were also made by this same institution. Information on the ocean temperatures and salinities at T-3 that had not been published previously, was furnished by L. V. Worthington of WHOI from field data obtained by Norman Goldstein and Charles Horvath.

Bottom cores obtained along the northern Ellesmere shore in 1954 will be discussed in a separate report by D. B. Ericson of Lamont Geological Observatory, Columbia University.

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MARVIN'S ICE SHELF JOURNEY, 1906

Vivian C. Bushnell*

THE extent of the ice shelf along the north coast of Ellesmere Island became of considerable interest in 1952 when Fletcher's Ice Island, T-3, was first occupied as a station for weather observations and geophysical studies by the United States Air Force. Aerial observations had shown the similarity between the surface features of the ice island and those of the ice shelf (Koenig et al., 1952). In order to make a thorough comparison of these large ice bodies and to obtain other geophysical data, a joint Canadian-United States expedition was made into the vicinity of Ward Hunt Island, near the centre of the ice shelf in the summer of 1954 (Hattersley-Smith, 1955). During this period Hattersley-Smith and Crary traversed the front of the present ice shelf between M'Clintock and Markham bays, collecting oceanographic data.

It was known from Peary's account of his 1905–06 expedition (Peary, 1907) that ocean soundings along the front of the Ellesmere ice shelf had been taken during the summer of 1906 by Ross G. Marvin, a member of the Peary party. A search of the literature produced no report by Marvin or by Peary on these soundings, although U.S. Navy Hydrographic Office Chart No. 2560 shows a few ocean depths in this area. In May 1954 a seventeen-page typed report written by Marvin was found in the Hydrographic Office files at the U.S. National Archives.

A limited amount of biographical material is available concerning Ross Marvin. According to Admiral Donald B. MacMillan (personal communication), who knew Marvin from the 1908–09 Peary expedition, Marvin had majored in civil engineering at Cornell University and had augmented his studies by spending some time on the New York state training ship, Saint Mary's. He had just graduated from Cornell in 1905 when he was chosen to go as a scientist with the Peary arctic expedition of that year (Stowell, 1954). Upon his return in December 1906, he accepted the post of instructor in the College of Civil Engineering at Cornell University. He held this position for the next two years, until he was granted leave of absence to join Peary again on his 1908–09 expedition. His untimely death on April 10, 1909, during the return of Peary's third supporting party, was most unfortunate. The photograph of Marvin shown in Fig. 1 has most generously been supplied by the Chemung County Historical Society of Elmira, New York.

Commander Peary, after his unsuccessful attempt to reach the pole in March and April 1906, travelled westward along the northwest coast of Ellesmere Island to the north end of Axel Heiberg Island, exploring the unknown area lying between the tracts visited by Aldrich in 1876 and by Sverdrup in

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Fig. 1. Ross G. Marvin.

1902. As stated in his book, Peary (1907) instructed Marvin to "run a line of soundings as far north from Hecla as practicable". Because of much open water, Marvin was not able to go north as instructed, so decided to travel west, taking soundings. This journey of Marvin's was made between June 2 and July 16. His report of this trip, quoted below, was evidently submitted to Peary who later transmitted it to the Hydrographic Office. No title had been given to the copy obtained from the Archives. No attempt has been made to edit this manuscript other than to correct obvious typographical errors.

* * *

The following report of the trip and results obtained by the summer sounding party is respectfully submitted.

Making the trip from the Roosevelt at Cape Sheridan to the cache at

Cape Hecla in company with your own western party, June 2nd-4th, we left Cape Hecla at 10.30 p.m., June 4th, to follow the trail of Captain Bartlett's party to the north. At the end of three hours, we left the former trail leading to Point Moss and followed the more recent trail along the young ice of the lead which had detained one of the supporting parties in the earlier spring work. At the end of a nine hours' march of steady going over smooth ice, we reached the point where the two trails met once more, this more recent trail cutting down the time consumed by several hours.

Camp was pitched here at 6.30 and as no cracks were visible, no sounding was attempted. It had been a night of very pleasant weather, but soon after turning in a fresh southerly breeze sprung up, which maintained throughout the noonday sleeping hours.

Broke camp here in the early evening and started on the march at 9.00 p.m., with all indications of making another good advance along the old trail. The igloos marking the end of the second day's advance on the spring trip were soon passed and by the end of four hours we had reached the point where the main party had been delayed by raftering ice and where the latter supporting party had been held up by open water, during the spring campaign. The southerly breeze had opened up the ice once more and a wide lead of open water extended indefinitely in both directions, the young ice having opened along a fairly straight line near its middle. This being the third party delayed right at the same point, it would seem to indicate a line of frequent fracture between the land locked ice and the outer area. A half hour of scouting made it evident that if we were to follow the former trail to the northward, it would be necessary to pitch camp here for the present.

The sounding machine was rigged on the sledge and a sounding taken on the edge of the lead. The wire belonging with the machine only half filled the barrel and upon trial, it was found to be too short. Some of the supply wire from the Roosevelt's sounding machine was spliced on and the barrel completely filled. On the second cast, a bottom of soft yellow mud was obtained at a depth of 158 fathoms. (The dry data of all soundings will be found tabulated at the end of this report.) A cloudy sky and a mist overhanging the land made it impossible to obtain either observations or land bearings.

Soon after midnight on Thursday, June 7th, the outside ice was setting to the northwest with the tide. Soon after 6.00 a.m., it had turned and was setting back again. This action of the ice continued with each turn of the tide. Obtained an a.m. time sight and a meridian altitude, also land bearings to fully determine our position.

Late in the evening of Thursday, we went to the westward along the edge of the lead with one sledge and the sounding machine in order to examine the lead and at the same time get another sounding. At the end of about four miles, the lead came right into the edge of rough rubble ice giving us no young ice to travel upon. As the lead extended as far as we could see, we halted here for our sounding. Paid out to the end of our line and got no bottom at 183 fathoms.

This showed us at once that we must devise some way of paying out the long coils of ship's wire if we hoped to obtain any results. We returned to our camp.

Before midnight of the 8th, after several hours work, we were able to give our new arrangements a trial at the edge of the lead and found several more changes necessary before it would be in working order. Before morning, it began to snow so we turned in once more to await developments of the lead and the weather.

On the evening of the 9th, we made a similar excursion to the eastward along the lead and at the end of six miles halted for a sounding. Similar bottom of soft mud at 151 fathoms. All the remaining soundings consisted of a similar bottom. A thick sky made bearings impossible. The whole northern horizon consisted of large patches of black water sky indicating other leads beyond the present one. No end visible to this lead in either direction. Returning to our camp, we made a few last changes in our newly arranged apparatus before turning in for our fifth and last sleep at this camp.

A small incident when breaking camp Sunday evening well illustrates the movement of the ice along the outer edge of this flaw. When first camped here, a pole which in March was about two miles to the eastward on the other side of this belt of unsteady ice, was not visible. On Friday, the loose pan from which we took our sounding to the westward, contained the sledge tracks which previously ran to the eastward of our camp. The pole was then close at hand, but in going to get it, the Eskimo found it to be still on the solid outside ice and so was unable to get it. On turning out this last morning, it was right alongside our tent, the pinnacle being jammed against the inner ice.

Got under way at 11.30 p.m., and travelled the young ice for only a short distance when we were forced to take to the old raftered ice, our trail of last Friday being broken by the constant running of the outside ice with every tide. This had widened the lead considerably but also filled it with loose floating fragments. This made our advance rather slow as we were forced to make a trail and the two pickaxes were in almost constant use.

At 3.30 a.m., we arrived at a suitable place for a cast. We halted intending to proceed again after the cast. While moving about along the edge of the lead, one of the men made a false step on soft snow and fell in the lead up to his hips. We then pitched camp and dried him before sounding. Later, we saw two seal in the lake outside and succeeded in shooting one of them, but having spilled his wind, he sank slowly to the bottom. Soft mud at 214 fathoms, bearings to also [sic] obtained.

As an advance along the spring trail had become impossible, we now decided to advance as far west as Cape Columbia, but to follow the edge of the lead and sound rather than cut into the smooth belt of ice-foot ice.

Broke camp and started our march again at 11.30 a.m. In addition to the rough going of yesterday, we were much delayed this day by soft deep snow which had to be traversed several times and packed before the sledges could advance. An overcast sky at the beginning of the march soon grew thicker and a fog began to settle down so that we were forced to pitch camp as we

could not see ahead of us to pick a trail over the rough raftered ice. Here we obtained sounding No. 4 with bottom at 232 fathoms.

On breaking camp in the evening, we were able to get our bearings and finally got under way at 11.00 p.m. The lead seemed to divide here, the two portions being separated by large pans which were adrift. The inner portion of the lead ran in more towards Cape Columbia. In the early morning, we were able to see ahead that the lead reached in nearly to the wide strip of smooth bay ice which stretches all along this coast. Our course was accordingly changed and set straight for the land in order to make better time to Columbia over this smooth ice. Just near the edge of the smooth ice, we found a narrow tide crack and so decided to camp here and take a sounding, nearly abreast Good Point, about 6 miles off-shore. A similar bottom at 162 fathoms.

We found a bed on the soft snow where a seal had been basking in the warm sunshine and so the two Eskimos set out in search of seal. Several hours later they returned with six eider duck which they obtained in a lake of open water a mile from camp. The eskimos say that the presence of these birds so early in the season indicates that the open water extends down through Robeson and Kennedy Channels. Upon leaving here, we cached a few articles of equipment and clothing which we had found superfluous.

With the better going on our next march, we were able to advance more rapidly at first but it soon became thick and foggy so that we were forced to follow the sinuous edge of the rough ice. Passed several places where the present lead ran into this edge, at other places all of this winter's cracks were a mile or so outside this edge. It finally became so thick that after seven hours of advance, we were forced to pitch camp for the day.

In the evening, the land was still overhung in places but Columbia appeared rather near, with a thick water sky to the northwest beyond Columbia. Began the march at 10.10 p.m., this being Thursday, June 14th. The same thick weather as yesterday forced us to make an irregular trail following the trends of the rough ice edge. About 3.00 a.m., a peak loomed up on the "Port Quarter". We kept on, however, to make sure of getting well out to the meridian of Columbia. At 6.30 it had cleared enough to show that we were well west of Columbia. We camped at once, hoping it might clear enough so that we could view the ice conditions outside and decide definitely our plan of work. While taking our sounding (88 fathoms), we obtained two black Guillomoy. The mud of this cast contained many short white hairs.

It had cleared when we turned out in the evening and we found ourselves nearer the land off the mouth of Clements Bay. The lead extended indefinitely to the westward and so after ten days of unsuccessful attempts, we were forced to give up all hope of getting out to the north to obtain any deep sea soundings. As the wide belt of bay ice along this coast seemed to extend indefinitely to the westward, to follow this seemed to be our only alternative left.

At the end of a nine hours march we camped off the mouth of Disraeli Bay. Bottom at 37 fathoms, with a few pebbles in the usual soft yellow mud.

Getting such a late start on our work as at present planned, it appeared

that it might be desirable to overstay the 30 days limit and so two men and one sledge were allowed to return to the ship from here. A four hours' march from here with the more heavily loaded sledge showed that a small cache would be desirable and so having reached a convenient point for a sounding, we camped once more, took our cast and made our cache before turning in for our rest. Also spent nearly an hour trying to get a shot at a seal in the open water. Bottom at 83 fathoms.

With clear weather this evening (Sunday, June 17th), we were able to set a straight course cutting across the large bights of smooth ice reaching far out and only touching at the successive inner points. At the end of a six hours advance, having seen no evidence of the lead we pitched camp at a place which seemed favorable for hunting the lead. A long scout, however, gave no signs of the lead and so we turned in.

Before turning out we heard a storm brewing and by evening a stiff breeze from the northwest was drifting the soft wet snow, forcing the party to remain in camp. The storm freshened during the night and by morning was blowing a light gale threatening the light tent at times.

There was nothing to be done except to await the end of the storm and this proved several days in coming. Thursday noon brought a temporary lull, but it immediately freshened again and it was Friday night, June 22nd, before we finally broke camp again.

At this late date, it seemed too late to attempt a trail to the north over the rough ice at a point so far to the westward, even if we were clear of the lead, which was by no means certain. And so we continued our westward advance with the even probability of meeting the lead once more.

At the end of a three hours advance, all the lashings on one side of the sledge gave away and we were forced to pitch camp and let the wood dry a bit before repairing it. The recent storm has made the going poorer. Spent several hours in scouting outside but no evidence of our former lead.

It was after midnight when we left this camp and after several hours marching, a point looming up ahead seemed to run in very close to the land just beyond McClintock Bay. We continued along the edge, however, and at the end of six hours were finally forced in to the shore just west of Cape Richards. The outlook from the top of the raftered ice showed that the smooth ice beyond here consisted merely of the usual narrow strip of ice-foot following the irregularities of the shore line.

Such further advance being unfitted for sounding purposes, we turned about at once and another hour put us to the outside edge of a large bight of smooth ice off the mouth of McClintock Bay, and a meridian altitude was obtained. The sun became overcast during the afternoon so that a p.m. sight was impossible, and we then turned in, expecting to spend the next day in getting a sounding, observations and bearings and resting the dogs a little before beginning the return march to the ship.

An a.m. sight for longitude was obtained, and then as several scouting trips showed no signs of open water, a hole was cut in a pan of this seasons ice and cast of 48 fathoms obtained. Bearings and other things completed,

we began our return march at 12.20 p.m. Monday, June 25th. Five and one half hours brought us to a strip of young ice at the edge of the smooth bay ice where we halted for a sounding, and it was destined to be a rather lengthy halt.

When the hole was finally completed through the thick young ice, the chisel fell out of the handle and sank to the bottom. The hole was still too small for the patent lead to go down through. As the temperature was about +35°F and water making on the ice surface, we left the lead suspended in the hole with the bare chance of its sinking its way down during our sleep. On turning out early next morning, we found the lead nearly a foot deeper but not entirely through the ice yet.

We succeeded in lashing the spade to the chisel handle and after some effort the hole made large enough for the lead. Lowered the lead as usual but found no bottom at the end of our coil, a little shy of 300 fathoms, instead of 500 as we had supposed the coil to hold.

Having had such shallow soundings all along, the spare coil had been left at the cache which was now nine hours to the eastward of our camp. Had another warm meal before undertaking this journey and then I set out at 1.15 p.m. with the empty sledge to go after our spare coil and ice chisel. A little misty upon starting and it steadily grew thicker so that I had difficulty in keeping the trail which the sun had already destroyed considerably. Soon found pools of water on the ice deeper than the sledge runners, which proved to be only a fore-taste of that to come further along on our return trip. Six and a half hours brought me to the cache. The return trip proved much worse as the dogs were thoroughly soaked and became cold and tired before the camp was reached at 3.30 a.m., Wednesday morning, having been over 14 hours on the road in making this trip.

As soon as we had our tea however, we proceeded to rig our coil which proved no easy task. After several trials, we finally got it in working order on the sledge upstanders and reached bottom at 10.25 a.m. Soft yellow mud at 429 fathoms and only five miles offshore.

Our rough rigging for the double coils made the work go slowly and it was 3.00 p.m. when we turned in once more, having been up since 5.00 a.m. of the morning before. Up to this time, it had been too thick for any bearings but being very anxious to obtain them for this deep cast we slept lightly keeping watch at times; and finally about 8.00 p.m. we obtained enough to fix the position of this our deepest sounding.

Finally left this place at 7.30 a.m. Thursday morning after a rather prolonged stay. Found more water than ever on the smooth ice. At the end of a five hours advance, we came upon a hole which seemed to indicate that our recent westerly winds had closed the former lead somewhat. As this was the only opening in sight, we camped here for a sounding. Soft yellow mud with a few white stones at only 33 fathoms. It is interesting to note that this the shallowest sounding of the trip is the one next east of the deepest cast; and they show a wide range from 33 to 429 fathoms.

Our next days march began at 8.00 a.m. in thick weather and after an hours advance it had become so thick it was very difficult to advance. We continued however and at the end of two hours, being at the lead once more we decided to halt for a sounding and await the clearing for fear of passing our cache in this thick weather. Sounding No. 12 gave 63 fathoms with a very soft yellow mud. It was necessary to lower the lead three times before the trap was sprung shut.

It cleared a little during the early morning and we obtained our bearings before leaving at 7.30 a.m. At the end of 1½ hours we reached our small cache. It has been utterly impossible to follow our outward trail for several days now as the warm sun has entirely destroyed it. Four hours to the eastward of the cache we found ourselves once more alongside the lead and so camped for the day.

Sounding No. 13 gave us 41 fathoms. The sample of the bottom contains many white hairs and a short bony like structure. When nearly ready to turn in the sun came out and we spent several hours in drying our clothes which had been constantly wet for several days.

The next morning, Sunday July 1st, we did not start the march until 9.00 a.m. After a few hours advance we came upon a stretch of young ice just outside and as this offered better going we followed it for some time. At the end of four and a half hours we came to the end and to a favorable place for a sounding. Being apparently well to the eastward of sounding No. 6 we halted for the day. The sample of this bottom at 90 fathoms contained a small piece of a white shell in the usual yellow mud.

On the next day's march we passed the lead at the end of the first hour but did not halt. At the end of four hours' advance we found another favorable place. We were only a little west of Cape Columbia and as it was nearing local noon, we decided to halt here and check our bearings with astronomical observations. Secured a meridian altitude and a p.m. sight for longitude.

This our fifteenth sounding gave us bottom at 87 fathoms. Spent the warm afternoon in drying our clothing and other gear and in overhauling the dog harnesses which were greatly in need of repair.

It thickened again during the night and soon after starting at 2.30 a.m. a fresh northwest breeze was blowing and a little snow was falling. At the end of two hours we halted and secured a cast of 88 fathoms, but no bearings. The entire halt here consumed an hour and a half. A little later we were again delayed a half hour in getting out of a large lake of water underlying soft wet snow. At the end of another two hours' advance we met the old lead once more. As it was still blowing and everything was wet we camped and turned in at once, hoping that the weather might clear.

For once our hopes were well founded, and it began clearing about 6.00 p.m. We turned out at once and after our usual breakfast found bottom at 64 fathoms with many fine white grains in the sample.

Just as we were hitching the dogs preparatory to starting at midnight,

we ushered in the Glorious Fourth by a single salute with our rifle fired toward Cape Columbia, whose twin peaks standing out like portals well justify the name "Columbia's Gates".

At the end of a four hours' advance we halted at the lead and secured another cast at 101 fathoms, which is a little deeper than the last ones have been. Thick and blowing so that no bearings were possible. Soon after starting again we were forced inshore by a wide point of rough ice but after rounding this we were led out once more on a strip of young ice which at the end of two hours brought us to another suitable point in the lead. We are now well to the eastward of Cape Columbia and so are getting deeper soundings once more. Soft mud at 224 fathoms.

It was after seven o'clock when we were finally ready to turn in. The only thing to mark the national holiday outside of our salute was the fact that we had put in a harder day's work than usual, having been on the go for over 24 hours, and having secured three soundings in that time.

We had not advanced far on our next day's march when we were delayed two hours in fixing the lashing of the sledge. During this delay the sky began to thicken rapidly. After another advance of 1½ hours we saw the lead open just outside and so stopped long enough to make a cast. Meanwhile, however, the Bos'n got into a lake of fresh water on the smooth ice and was wet to the skin up over his waist. This accident together with the thick weather which would easily lead us past our small cache, persuaded us to pitch our camp here. Bottom at 80 fathoms.

A westerly breeze soon veered to the northwest and began to freshen so we took a good rest and sleep here, and did not get under way until the next morning at 5.00 a.m., Friday, July 6th. A three hours' advance brought us to the small cache and after another advance of four hours we halted to camp, as we were near a crack in the young ice outside. Sounding No. 21 gave us bottom at 150 fathoms.

Leaving here Saturday p.m. a long march landed us at Cape Hecla, after a break down which kept us over 24 hours on the road.

No further soundings were attempted and from Cape Hecla the return to the ship, then at Lincoln Bay, was made without incident except constant delays by the thick snowy weather and the great amount of fresh water covering the ice. Our sledge and most of the outfit had to be abandoned near Cape Rawson and the ship was finally reached on foot about midnight of Monday, July 16.

* * *

In addition to the journal presented above, a seven-page data table was included with the Marvin report. This table listed dates, ocean depths, horizontal angles to various capes and mountain peaks, and magnetic bearings to the same points. The few sun observations noted in the journal have not been found.

The 1954 expedition (Hattersley-Smith, 1955) also measured horizontal angles to mountain peaks as a means of determining positions along the front of the ice shelf. Determination of accurate locations by sun lines was

considered impractical. Therefore, locations for both the 1906 and the 1954 expeditions were determined from horizontal angle difference between mountain peaks or features which were visible or by interpolation between these for times when clouds obscured the peaks. Through the cooperation of the Canada Defence Research Board and the Canada Department of Mines and Technical Surveys, Aeronautical Chart Section, a map was obtained that was sufficiently accurate to make use of these observations. Much credit is due to their Photogrammetry Section for the fine map that they produced. Surface photographs taken by Hattersley-Smith in 1954 and aerial photographs of the same localities were used to identify specific mountain peaks that were then located on the map. The sites of the oceanographic stations in 1906 and 1954 are shown in Fig. 2.

One discrepancy is noted in the Marvin locations. This concerns the cache mentioned at site 8. Station 12 of the return trip falls east of this site, though from the wording of the journal it appears to have been west of it. These conflicting statements are reconciled when we assume that Marvin also established a cache at site 7, from where one sledge returned to the Roosevelt. A further cache, including the sounding wire, was left at site 8, the wire being obtained later in order to find the depth of water at site 10. Thus, the cache to which he refers as being past site 12 would be the one located at site 7.

Some interesting comparisons can be made between Marvin's observations and those of Hattersley-Smith and Crary. The first of these concerns the extent of the ice shelf. Marvin makes it clear that, beginning with his fifth sounding, he followed the ice front as it existed at that time. As the line soundings could be made most easily in areas of open water that were usually available immediately off the ice shelf, the logical path of travel would be along the ice front. He mentions the "smooth belt of ice-foot ice", the "wide strip of smooth bay ice which stretches all along this coast", etc. Therefore, by locating Marvin's soundings, beginning with the fifth, to his farthest west and back, we are actually tracing the extent of the ice shelf in 1906. This is also true of the sounding stations in 1954.

The ice shelf which was present in 1906 to the west and to the east of that found in 1954 has undoubtedly been the source of ice islands at some time during the intervening period. In 1947 one such island was photographed just north of Good Point. The close proximity of the site where it was found to its rather obvious place of origin at the eastern end of the ice shelf, leads to the conclusion that it had broken away only a short time before it was photographed in the summer of 1947. When the outline of this island is drawn on the map in the area from which it originated, its northern extremity coincides with the ice front as it had been found by Marvin in 1906. It will be seen in Fig. 2 that the extent of the ice shelf between longitudes 73° and 78°W was the same in 1954 as it was in 1906.

Another point of similarity between Marvin's observations and those of Hattersley-Smith and Crary concerns the pack ice conditions north of Cape Discovery. In both cases the pack ice found immediately to the north of the ice shelf was of a permanent nature and badly hummocked. In fact, Marvin

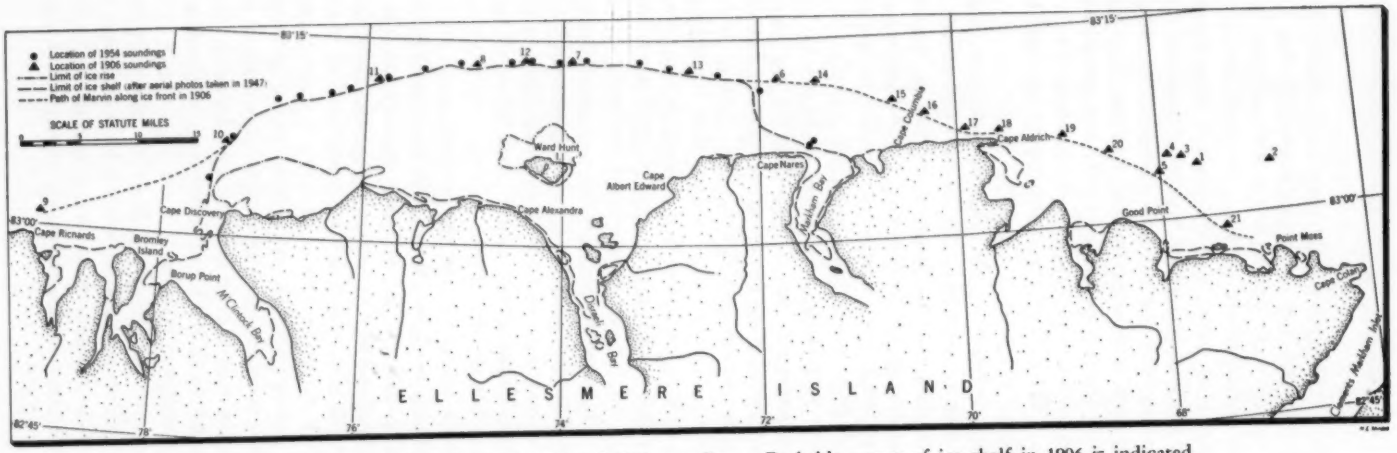

Fig. 2. Map showing locations of 1906 and 1954 soundings. Probable extent of ice shelf in 1906 is indicated.

found no open water at all, and the 1954 party succeeded only by sledging over the rough pack for approximately one mile.

It must also be pointed out that Marvin does not mention the "rolls" or ridge and trough systems that are generally characteristic of this ice formation. In the survey taken in 1954, the rolls were absent in the last mile of shelf width nearest the pack ice, and elevations of this outer strip were only about five to ten feet above sea level. It is presumed that it was much the same in 1906.

All comments made above in regard to conditions in 1954 are based on information furnished by A. P. Crary. The finding of the Marvin report is due largely to the efforts of personnel at the U.S. National Archives, whose assistance is gratefully acknowledged. Biographical information on Marvin obtained from Admiral D. B. MacMillan and J. V. Stowell was most interesting and helpful.

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THE *CALANUS* EXPEDITIONS IN THE CANADIAN ARCTIC, 1947 TO 1955*

M. J. Dunbar†

THE recently reorganized Arctic Unit of the Fisheries Research Board of Canada, with headquarters at McGill University in Montreal, is a development of the Eastern Arctic Investigations that began in 1947. The *Calanus*, a diesel ketch of 43 tons, was built in Nova Scotia in 1948 (Dunbar, 1949); her name has been taken to cover all the field work of the series, including the seasons of 1947 and 1948 before the *Calanus* was used, and the work of individual members of the staff not attached to the ship.

The work done on the *Calanus* expeditions consists of the collection of material for the study of the abundance, distribution, and breeding cycles of sea mammals, fishes, plankton, and benthos. The emphasis has varied from season to season according to the particular nature of the region of operation and in relation to the needs of development and improvement of Eskimo economy. More time has been spent on mammals, especially walrus, ringed seal and beluga from 1953 to 1955. Collections of plankton and benthos were only qualitative in the first years. Quantitative work on both was begun in Frobisher Bay in 1951, and since 1954 efforts have been made to attack the problem of the rate of production of organic material in these cold arctic and subarctic waters. Physical oceanographic observations, including hydrographic sections, have been made on all expeditions. Oxygen concentrations have been measured since the start of operations, and phosphates since 1951.

The results so far available, whether published or not, are summarized below, following a brief account of the area of work, personnel, and logistics of each year's expedition. Station lists for all years to 1954 incl. have been published (Dunbar and Grainger, 1952; Grainger 1954b; Grainger and Dunbar, 1956).

1947. A reconnaissance of Ungava Bay was carried out by the author, assisted by H. Hildebrand, then a graduate student at McGill. Students have been employed as summer assistants every year, and the training of young men in northern work has been an important part of the programme. The party worked the coastal waters of the bay from Payne Bay to Koksoak River in a 30-foot "trap-boat" during the first half of the summer. In the second half work was done in the eastern part of the bay, from Koksoak River to Port Burwell in a 40-foot native-owned Peterhead boat.

*This paper does not mention arctic and subarctic work of the Fisheries Research Board before 1947. The northern work began in 1944 in northwestern lakes and rivers. (*See* F. R. B. Bulletin No. LXXII.)

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1948. Hildebrand worked on two lakes in the vicinity of Fort Chimo in March and April to obtain information on freshwater conditions in the winter.

Hildebrand and Ph. Orkin accompanied an Eskimo hunting party during late June and early July to work on ringed seal (*Phoca hispida*) and bearded seal or squareflipper (*Erignathus barbatus*). The second half of the summer was spent in the vicinity of Port Burwell, the work there being concerned mainly with the Atlantic cod (*Gadus callarias*).

E. H. Grainger was attached to a commercial fishing venture as observer, in order to begin a study of the arctic char (*Salvelinus alpinus*) at the head of Frobisher Bay. The *Calanus* was built during this summer and was sailed north to Fort Chimo by Ernest Ritchie, with W. E. Wilson (engineer), Kingsley Morisson, and Constable Hayley of the marine section of the R.C.M.P. Hayley replaced Dunbar, who was invalided ashore at Halifax. The boat was beached at Chimo, using cradle and winch.

1949. This was the first season in which the *Calanus* was used in field work. The ship's company consisted of Dunbar, Grainger, Wilson, T. Creery, E. Reid, and two Chimo Eskimo. The boat was launched on June 16 and entered Mission Cove harbour at Burwell on June 29. The eastern half of Ungava Bay is always clear of ice before the western. Hydrographic sections were made across the bay, using Akpatok Island as the hub. The Button Islands were visited and a considerable part of the season was spent at Port Burwell.

1950. The work in Ungava Bay was continued, with emphasis on experimental fishing, especially for Greenland shark (*Somniosus microcephalus*). Some time was spent in the vicinity of Cape Hope's Advance and Diana Bay (which had been visited also in the previous year), and a section was made across Hudson Strait from Wakeham Bay to Big Island. Work at Burwell and in the Button Island group was continued. On another project, J. Wright accompanied the same commercial fishing venture that Grainger had joined in 1948, working on the arctic char in Frobisher Bay and on the Atlantic cod at Resolution Island (Acadia Cove). A. H. Lawrie accompanied the U.S. Navy Resupply Mission to the far northern stations as observer for the Fisheries Research Board. The *Calanus* was again beached at Chimo for the winter, as in the two previous years.

1951. With Dunbar, Lewis, I. McLaren, W. E. Wilson and T. E. Wilson on board, the *Calanus* spent a few weeks in the eastern part of Ungava Bay, paying special attention to the little fiord of Adlorilik. She then crossed Hudson Strait to Lake Harbour and arrived at the Frobisher R.C.A.F. base on August 1. The month of August was spent entirely within Frobisher Bay, carrying out an elaborate series of sounding runs, dredging, trawling, and plankton hauling. The ship was beached at the Frobisher air base.

Grainger spent the season at the Sylvia Grinnell River in Frobisher Bay, making an intensive study of the arctic char. Lawrie took part in the *Cancolim II* expedition into the Beaufort Sea in the western Arctic as marine biologist for the Board. This was the first extension of the field of operations into the West.

1952. Grainger, McLaren, W. F. Black, T. E. Wilson, and an Eskimo pilot took the *Calanus* into Cumberland Sound. The working season was cut short by mechanical trouble and the party had to return to Frobisher for temporary repairs, after which the ship was taken at reduced speed to Churchill for repairs and wintering. J. Martin and S. McCall joined the ship's company for that trip. Some of the roughest weather of any of the expeditions was encountered on this voyage together with further mechanical trouble and Grainger's party did exceedingly well to bring the crippled *Calanus* safely into Churchill harbour.

McCall and A. Dawson had been working during the summer on Ogac Lake on the southwest shore of Frobisher Bay, in which exists an isolated population of Atlantic cod (see page 184). This work was supported by the Carnegie Arctic Fund of McGill University, but the results will be incorporated in due course into the *Calanus* expedition series.

1953. For the work in Hudson Bay, which is a very large inland sea, a professional skipper was engaged for the first time. This post was filled in 1953 by R. Collyer. Grainger was again in charge of the scientific work and assisted by McLaren, Black and Dawson. The field work covered northern Hudson Bay and the western end of Hudson Strait, and a beginning was made in the study of the northern Hudson Bay herd of walrus (*Odobenus rosmarus*) that is to be found in summer first at Walrus Island, then at Bencas Island and the northern end of Coats Island, and still later at Seahorse Point, Southampton Island.

1954. Captain H. Norden Andersen took over as skipper, with Wilson still as engineer. The scientific party consisted of Dunbar, Grainger, and J. A. Thomson. The field work was very largely on the walrus at Walrus Island, Bencas Island, and Coats Island. Grainger spent several weeks at Coats Island with two Eskimo tagging walrus and collecting material. Thomson left in August and the remainder of the party sailed the ship to Montreal, where she was given her first refit. She was fitted with a new magnetic compass, a Sperry gyrocompass, a new and more powerful radio, a new auxiliary engine, and a set of hydraulic winches from Scandinavia (main trawl winch, hydrographic winch, and anchor windlass). All hatches were renewed and rearrangements made in the space below decks.

McLaren spent the period from March to October in the Cape Dorset area of Baffin Island, making a thorough study of the ringed seal. Dr. F. Neave, of the Nanaimo, B.C., Station of the Fisheries Research Board, accompanied an ice-breaker and supply mission in the Beaufort Sea, to make a reconnaissance of fisheries research needs in that region.

1955. The *Calanus* left Montreal at the end of June with Andersen, Grainger, McLaren, Black, and Wilson on board; Dawson served as supernumerary as far as Battle Harbour, Labrador. The ship was greatly delayed by unusual ice conditions on the Labrador coast; this provided opportunities for some interesting work on plankton production, and on cod at Nain. The late arrival at Coral Harbour made it necessary to abandon the work planned for the southeastern part of Hudson Bay. The party was joined at Coral

Harbour by A. Mansfield, who had been working from there on walrus since late March, on a grant from the McGill Carnegie fund. The work of 1954 at Coats Island was continued. Wilson left early in September, and Mansfield continued his work on walrus by accompanying an Eskimo hunting party to Seahorse Point and returned to Montreal in October. The remaining four took the ship through Roes Welcome Sound and Frozen Strait to Igloolik, where she was frozen-in in October. Black and McLaren left a little later for Montreal, leaving Andersen and Grainger as wintering party on board. A winter station was established through the ice in some 50 metres of water in Foxe Basin for the observation of the winter regime in plankton and benthos, and work began at the same time on walrus and ringed seal; northern Foxe Basin is one of the few places where walrus are known to winter.

D. Sergeant spent the summer studying the beluga (*Delphinapterus leucas*) in the area of Churchill, where a commercial company has a license for the limited exploitation of the beluga. Material from 200 whales was collected with the aid of a whaleboat. The *Calanus* group now has two powered whaleboats in commission, one at Coral Harbour, the other at Churchill.

J. G. Hunter, attached to the Nanaimo Station, joined the group in 1955 in order to begin work on the fishes of the coast of Beaufort Sea from Herschel Island to Baillie Island, studying the fully marine, as well as the anadromous species. The chief purpose of this work is to establish the biotic potential of these fishes, with a view to a rational development of native fisheries.

The author was in charge of these investigations from 1947 to 1955 on a part-time basis. They have now grown so large that full-time control is essential. In 1954–55 the group was reorganized and the staff considerably enlarged. Dunbar remains as consultant and adviser, and the present full-time staff is as follows:

Dr. H. D. Fisher (in charge)	Mr. A. W. Mansfield
Dr. E. H. Grainger	Miss B. M. Barry
Dr. D. E. Sergeant	Captain H. N. Andersen
Mr. J. G. Hunter	Miss L. McMullen
Mr. A. S. Bursa	Miss J. Thompson
Mr. I. A. McLaren	Mr. T. E. Wilson

Captain Andersen, who has had five years' experience with schooners on the west coast of Greenland, is skipper of the *Calanus* and general technical assistant. Miss L. McMullen is secretary and general assistant to Dr. Fisher.

Summary of results

Physical oceanography

The map Fig. 1 shows the hydrographic sections made up to 1954, and the waters covered in the field work. Sections in Ungava Bay show a flow of water into the bay from the northwest, across its central part south of Akpatok Island, and out in the northeast, this last flow being pressed against the Labrador side. Akpatok Island sits on a shelf extending eastward from the island (which is of Palaeozoic limestone, in contrast to all the rest of the

Fig. 1. Hydrographic sections and working areas of the *Calanus* expeditions.

Ungava Bay rocks), and there is a trench with depths of over 200 metres surrounding this formation. No good trawling bottom was found in the bay; the bottom is exceedingly uneven and apparently boulder-strewn. The water is of low temperature and of low salinity, but the upward trend of these two parameters that is commonly encountered at depths below 200 metres probably indicates the entry of Atlantic (West Greenland) water into Ungava Bay at these depths. The upper water of the bay shows great dilution by land drainage, and Atlantic influence is not demonstrable from hydrographic data; admixture of Atlantic water is, however, strongly suggested by the plankton, which is subarctic rather than arctic (for the criteria used to delimit the two marine regions see the paper on the Ungava amphipods (Dunbar, 1954)), by the amphipod fauna, and by the presence of two fishes, namely the Atlantic cod in the northeast part of the bay, and the Atlantic salmon (*Salmo salar*) in the rivers of the eastern and southern shores, as far west as the Koksoak.

Mixing of the waters of Ungava Bay and also of Hudson Strait and Frobisher Bay appears to be facilitated by the establishment of density inversions, probably for short periods of time only. Density inversions, which are not yet fully accepted as respectable by the oceanographic world, began to appear in the *Calanus* results from 1949 onward, and there is evidence that they are associated with strong tidal currents and large tidal intervals (Dunbar, 1955).

Exceptional hydrographic conditions were found in Adlorilik, a small fiord on the eastern side of Ungava Bay. This is an inlet that is well over 100 metres deep and that has a very shallow sill at the entrance. In contrast to the usual conditions in such fiords in the North, as in Victoria Bay on the shore of Frobisher Bay or in fiords in Greenland, where the deep water inside the fiords is much colder than the water at similar depths outside the fiords, the deep water of Adlorilik was found to be very much warmer than the corresponding water outside (3°C. at 80 metres inside compared with 1.2°C. outside). Possibly this is a wind effect.

From the sounding runs made in Frobisher Bay in 1951 an interesting pattern was brought to light, the two main features of which are (1) a deep trough along the southwest side of the bay, extending from a fairly low threshold at the mouth (about 275 metres) to the islands that separate the outer and inner bays; this trough is often deeper than 550 metres, and sometimes deeper than 640 metres, which is beyond the limit of the sounder scale of the *Calanus*; (2) a shelving bank in the northeast half of the outer bay extending from the level of Wiswell Inlet to at least as far as Loks Land. This bank, now known as the "Calanus Shelf", slopes gently from very shallow depths near the shore to some 130 metres before meeting the deep trough already described. Bottom temperatures over this shelf were of the order of -0.5°C. in 50 metres in August 1951, and trawling over the shelf as a whole gave very poor results.

Fishes

The collection of fishes from Ungava Bay has already been published (Dunbar and Hildebrand, 1952), and only features of the fish fauna that are of zoogeographical interest are referred to below. Special attention has been given to the Atlantic cod of the Port Burwell area and to the arctic char of Frobisher Bay. These two species, together with the Greenland shark, and perhaps the Greenland halibut (*Reinhardtius hippoglossoides*) form the small group of fishes which offers possibilities of development in the interests of the Eskimo economy in restricted localities of the Eastern Arctic. The shark is easily caught wherever seals are abundant along the eastern shores of this region, at least from Cape Chidley and Burwell to northern Baffin Island; it does not appear to be common in Hudson Strait or in Frobisher Bay.

The Atlantic cod arrives at Burwell in late July or early August and leaves again in September-October. During that short period, however, large numbers are present, and it can be taken at the rate of about 20 fish per

man-hour. Long-lining was not successful at Burwell, perhaps owing to the shortage of good bait. Burwell is the only region in the whole of the Canadian Eastern Arctic, except the Labrador coast, that offers a cod fishery. The fish are small and the rate of growth is slow, a 60-cm. specimen being 12-13 years old. The possibility of developing a fishery in Ungava Bay has been discussed elsewhere (Dunbar, 1952).

A study of the biology of the arctic char, as regards its breeding cycle, growth rate, and sea-life, has been published by Grainger (Grainger, 1953), who has shown that the char of the Sylvia Grinnell River, at the head of Frobisher Bay, can reach an age of more than 24 years and a length of approximately 70 cm. The first migration to the sea occurs probably during the fifth to seventh summer, and the sea-life each year lasts from late June to late July or early September. The females reach sexual maturity at a length of about 54 cm. and an age of about 12 years. Egg counts of maturing fish averaged 3,590, and apparently only one third of the females over 12 years breed in any one year. From these results, and without yet knowing the mortality of the young in fresh water, it was concluded that the char population of a single stream could be seriously damaged by intensive fishing, especially on a commercial scale. At the same time it became clear that many char streams were not touched at all by the Eskimo, and that almost no effort was made to preserve the fish caught. The key to the development of this important resource lies, therefore, in providing greater mobility of the Eskimo and in encouraging the preservation of the char for winter use by smoking, salting, or freezing.

Ogac Lake, a small lake on the southwest shore of Frobisher Bay, has long been known to contain cod. The *Calanus* expedition of 1951 found that these are *Gadus callarias* and that they live completely isolated from the main marine population of cod. Atlantic cod are not known from Frobisher Bay itself, or from anywhere north of Resolution Island in the Canadian Eastern Arctic. The cod of Ogac Lake live in a layer of water of about 26.00‰ salinity or less and of temperatures of the order of 7-8°C., which is far above the temperature of the water in the adjacent fiord (Ney Harbour). This stratum lies between fresh water at the top and stagnant salt water at the bottom. There is contact with the fiord water at spring tides, but the cod apparently do not pass over the sill out of the lake. Fish of all sizes were taken in the lake, including large individuals of over four feet in length. The vertebral count is very low (51-52), indicating development in warm water. This cod population may have invaded the lake during a past period of warmer climate, at a time when cod were normally present in Frobisher Bay in summer.

Marine mammals

Walrus The walrus herd of northern Hudson Bay frequents in summer Walrus Island, Bencas Island, Coats Island, and Seahorse Point on Southampton Island, in that order, appearing at Walrus Island in July and at Seahorse Point in late August and September. Possibly some of them go south to the Belcher Islands during that period. An estimate of the numbers in the herd

is difficult to make at this stage; the present estimate is 3,000 animals. For the groups seen a ratio of one first-year young to every ten adults and adolescents was inferred. Of 18 specimens taken in 1954 five were males and 13 females. Of the females one was first-year, one second-year, two had newly-born young, and four were pregnant.

As a preliminary experiment, 23 walrus were tagged in 1954 with a new stainless steel tag designed by the writer (Fig. 2). The tag is about 1½ inches long and is designed to pierce the very tough hide, and lodge with the head in the layer of blubber and the basal disc on the outside of the skin. In 1955, 48 animals were marked, and the tagging is to be continued on a larger scale.

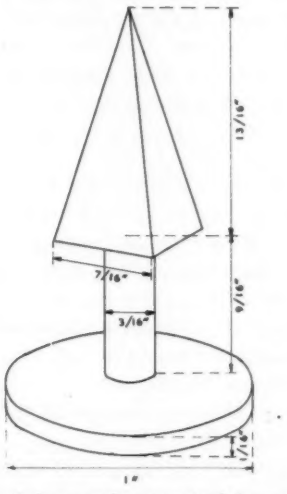

Fig. 2. *Calanus* walrus tag (stainless steel).

The walrus haul out on rocks of a certain shape that is not found everywhere in the north. Much of the shore-line is either very steep or very flat and not suitable for walrus. They prefer a sloping rocky shore that rises in terraces or otherwise unevenly to some few tens of feet above the water level. Since no significant difference was found between the benthonic food supply close to these rocks and the supply in other areas, it was concluded that an important factor in determining the walrus distribution in the summer may well be nothing more complex than the conformation of the shore. The winter distribution of this herd is still unknown; the tagging is expected to shed light on this.

Ringed seal. The *Calanus* has worked in areas rich in seal only since 1951. Intensive work on the ringed seal began at the western end of Hudson Strait in 1953. In that year, McLaren's material consisted of 44 animals. In 1954, working at Cape Dorset from March to October, he collected material from 498 specimens. Some of the results of this work, which will be published shortly, may be summarized as follows (McLaren, 1955):

The ringed seal is not a truly migratory animal and it appears that the decisive factor governing its distribution in the Arctic is the duration of the ice cover. This is formed earliest and persists longest along irregular coasts with much skerry development, and there appears to be a correlation between the pattern of the coast line and the seal distribution. By far the most important food organism, especially in offshore waters, is the pelagic amphipod *Themisto libellula*, but it is clear that the distribution of this crustacean has little to do with the distribution of the seal. In shallower inshore waters, seals feed to a large extent on decapod crustaceans, Mysids, and polar cod.

The study of the teeth of the ringed seal has shown that the fact that this species is a solitary form, and not a migratory and harem-breeding species, complicates the interpretation of the tooth-sections, since there tends to be a wide range of nutritional histories. The oldest individual, a male, was a little over 40 years old; very few were more than 20-25 years old. The male does not mature on the average until the seventh year; most of the females ovulate for the first time when about six years old, although a few may do so in their fifth year. "Testis histology reveals that the males are capable of fertilizing from late March until at least mid-April and that they are out of rut by late May and probably earlier. The females normally ovulate shortly after parturition, during lactation. Mating probably occurs shortly after the birth of the young. The young adult females may tend to be polyœstrous; older seals, possibly by fixation of the œstrous cycle through pregnancy, probably lose this tendency. . . . . The blastocyst remains unimplanted for a period of more than three months and individual embryos may implant over a period of about one month. . . . . The peak of pup production probably occurs near the beginning of April and the females may attend the young until mid-June, or later in some cases." (McLaren, 1955).

Beluga. A preliminary survey of the white whale population of western Hudson Bay was carried out by the Central Station of the Fisheries Research Board, when a license for commercial exploitation at Churchill was first granted (Doan & Douglas, 1953). Sergeant, of the Arctic Unit staff, began a thorough study in 1955 and examined 200 individuals. By aerial reconnaissance 2,700 white whales were counted on July 25; 900 in the Churchill River estuary and 1,800 near the mouth of the Seal River. By August 30 the whales had left the estuaries and were presumably on migration. A whale tag that is to be fired from a crossbow and which lodges in the blubber has been developed and will be used in 1957. Work is planned also on the beluga of the Mackenzie Delta.

Zoogeography and systematics

In the large-scale marine zoogeography of the north, the delimitation of a subarctic from an arctic marine zone has already been proposed by the author (Dunbar, 1954), and this system is used in discussing the present expedition results. The *Calanus* has worked so far on the northern fringes of the subarctic zone (Ungava Bay, Frobisher Bay, and Cumberland Sound),

and in the special region of Hudson Bay. Hudson Bay, although definitely outside the subarctic waters on the criteria used here and showing many of the characteristics of the arctic zone, nevertheless has to be placed in a category by itself on account of the high temperatures and low salinities in the upper layers in summer (up to 10°C. and down to about 23.00‰), a result of freshwater influx and very high stability, and on account of the preservation of warmer-water relicts, such as the caplin (*Mallotus villosus*) and the calanoid copepod *Acartia clausi*.

It has been established as a general rule that in the arctic zone the macronecton is dominated by mammals, with the fishes of minor importance and represented by comparatively few species, but that in the subarctic zone the macronecton is made up almost entirely of fishes, with the mammals relatively unimportant.

The northern limits of the distribution of the fishes of economic importance in the north, that is to say, of all fishes produced in large numbers, occur either close to the northern edge of the subarctic or well within it. The Greenland shark and the arctic char are the only exceptions, and the latter is an anadromous fish with a very short sea-life. The reasons for this striking distributional pattern are not clear, but they are no doubt connected with the different capabilities of homoiothermous and poikilothermous animals, and possibly with the time required for the adaptation of large poikilotherms to very cold environment.

In general faunistic and systematic studies, work in the following groups has been done, some of which has already been published: Fishes of Ungava Bay (Dunbar & Hildebrand, 1952); amphipods of Ungava Bay (Dunbar, 1954); polychaetous annelids (Grainger, 1954a); echinoderms (Grainger, 1955); cirripedes (Bousfield, 1955); priapulids, sipunculids, and pycnogonids of Ungava Bay, eastern Hudson Strait, Frobisher Bay, and Cumberland Sound; and the plankton copepods of Ungava Bay (Fontaine, 1955). Among the benthonic forms, including fishes, are many new records for the area and several for North America, and there are five new species of amphipods. The zoogeographic affinities of the fishes, annelids, echinoderms, and amphipods are as follows:

Fishes: 44 species, of which 13 are freshwater forms. Of the marine species 3 are arctic, 10 are arctic-subarctic (panarctic), 2 are subarctic, 5 are subarctic-boreal, 2 are typically boreal forms, and 8 are of wide north-to-south range from arctic to boreal. Two of the panarctic species, *Icelus spatula* and *Eumesogrammus praecisus*, are not known east of Greenland or west of the Kara Sea, and are probably of Pacific origin.

Only five of the total number are known to be circumpolar, though several others probably are.

Polychaetes: 74 species. Circumpolar or probably so, 42 species; panarctic, 15; arctic-subarctic-boreal, 49; "cosmopolitan", 9; probably of Pacific origin, not known east of the Canadian Eastern Arctic, 3. (In all, 134 species of polychaetes are now known from the Eastern Arctic, of which 8 belong to this Pacific group).

Echinoderms: 26 species. Circumpolar or probably so, 14; panarctic, 13; arctic-subarctic-boreal, 10; Pacific species known only as far east as Greenland, 2. *Amphipods*: 114 species. Circumpolar or probably so, 45; arctic, 3, perhaps 7; subarctic only, 13; panarctic, 32; panarctic-boreal or subarctic-boreal, 57; recorded also from the Japan Sea or the Sea of Okhotsk, 33; known only from the Atlantic sector, 28, of which 12 belong to the single family Stenothoidae; Pacific forms not known west of the Kara Sea or east of Greenland, 6.

In all four groups there is a certain small proportion of species that are known only from North America and Siberia, but not from the intervening European waters. These are very probably immigrants to both regions (North America and Siberia) from the Pacific by way of Bering Strait. They are thus in the same category as certain species of decapod crustaceans known from the West Greenland coast, and of certain fishes known from Hudson Bay (Vladykov, 1933). It is also interesting that Doutt (1942) found that the freshwater harbour seal (*Phoca vitulina*) from the Seal Lakes of the Ungava Peninsula showed closer affinity to the Pacific than to the Atlantic subspecies.

Plankton production and standing crop

The Ungava Bay copepod plankton (harpacticoids excluded) has been found to contain 22 species, 5 of which had not been previously recorded from the western North Atlantic (Fontaine, 1955). With one exception, the species are all panarctic in distribution; the exception is the boreal form *Pleuromamma robusta*, of which only two specimens are recorded from Ungava Bay. *Calanus finmarchicus* breeds continuously in the short summer, but apparently goes through only one generation per year. The same is true of *Pseudocalanus minutus*, but it is possible that in this species part of the population breeds a second time in the fall. *Ascartia longiremis* and *Oithona similis* spawn in July, probably producing only one generation per year.

The breeding cycles, growth rates, and metabolic rates of cold water holoplanktonic animals are matters of considerable general interest upon which much work has still to be done. Evidence has been brought forward by various workers that growth rates of certain littoral and benthonic species are not lower in cold arctic waters than those of the same or closely related species in temperate and even subtropical waters, and that the same is true of the metabolic rates measured in terms of oxygen consumption. It appears clear, however, that in the holoplanktonic species so far studied, the growth is much slower in cold water. The measurement of the metabolic rates is the next step in this particular line of research, and is planned for the immediate future in the *Calanus* series. For a general review of recent work on metabolic regulation with respect to temperature in poikilotherms see Bullock (1955). The breeding cycle in the large pelagic amphipod *Themisto libellula* is at present under study; its growth is slow, and its life cycle appears to take two years, with only one breeding period per individual. Similar work will shortly be undertaken on the Euphausiacea.

Hudson Bay is intensely stratified in the upper 50 metres in summer, so much so that there has been doubt expressed as to whether a normal vertical exchange during the winter is achieved; until a few years ago it was also thought possible that the water below 50 metres was dynamically dead and therefore might be expected to be very low in oxygen content. As regards the former possibility, hydrographic work has now been carried out in the winter, but the results are not yet available. The oxygen content of the deep water in Hudson Bay is normal, and there is therefore no reason to suspect unusually poor conditions for the production of phytoplankton or zooplankton. The standing crop of zooplankton is not much below that of Ungava Bay, judging from present results; and the phytoplankton, according to Mr. Bursa's work with the plankton (Utermöhl) microscope, maintains a standing crop in summer that is only a little below that of the western end of Hudson Strait, where the stability of the water is much less.

The standing crop of plankton has been sampled by means of (1) the two-metre stramin net hauled horizontally, (2) the Henson net with No. 6 bolting silk hauled vertically, and (3) water samples preserved in weak neutralized formalin for estimation with the Utermöhl microscope. Measurement of the rate of production of organic matter in Hudson Bay is being undertaken at present by means of the oxygen (Winkler) method. The results promise to be very interesting, for they suggest that the method may need considerable modification, and that there may be factors not yet considered, such as the possible dampening of zooplankton activity in the darkened bottle, and even the possibility of a considerable lag in the cessation of synthesis of organic matter in the dark, which complicates the interpretation of the results, and which may apply especially to the use of the method in water of very low temperature.

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MAMMALS OF THE KATMAI NATIONAL MONUMENT, ALASKA

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In the summer of 1953 a programme of scientific research that included a biological reconnaissance was initiated in Katmai National Monument by the U.S. Park Service. The Arctic Health Research Center and other agencies of the Federal Government were invited to participate in this work. The writers were given the opportunity to survey the mammals of the region and to make observations on the ectoparasites and endoparasites of the animals collected.

It is the purpose of this paper to present information obtained on the occurrence and distribution of the mammals of the region.

Background information

Katmai National Monument, comprising about 1,700 square miles located at the base of the Alaska Peninsula, was established in 1918 to protect the area most drastically affected by the volcanic eruption of 1912. In 1931 and 1942 the boundaries were extended to include additional areas of geological and biological interest.

The monument is traversed on the west side by the Aleutian Range, and its topography is quite mountainous. Except where extensive glacial outwash has led to the formation of low valley floors and pumice beaches, the shoreline is characterized by deep estuaries, lagoons, and numerous small islands. The highest peaks reach an altitude of 7,500 feet; many of the steep slopes are covered by a thick layer of volcanic ash. Craters of extinct volcanoes are numerous, and seven volcanoes were active during the time of this work. The Valley of Ten Thousand Smokes that was formed during the eruption of 1912 lies below the western slope of the Aleutian Range. This area was described in detail by Griggs (1922). Vegetation is gradually becoming re-established in this valley. West of the Aleutian Range the foothills border a series of large lakes. A nearly level plain with many ponds and lakes, including Becharof and Ugashik lakes, extends from the foothills of the Aleutian Range south-westward to Bristol Bay.

The region where the field work was performed lies in a transitional zone between the Hudsonian and the Aleutian biotic provinces (Dice, 1943). The vegetation, climate, and mammals of this region were discussed by Osgood (1904).

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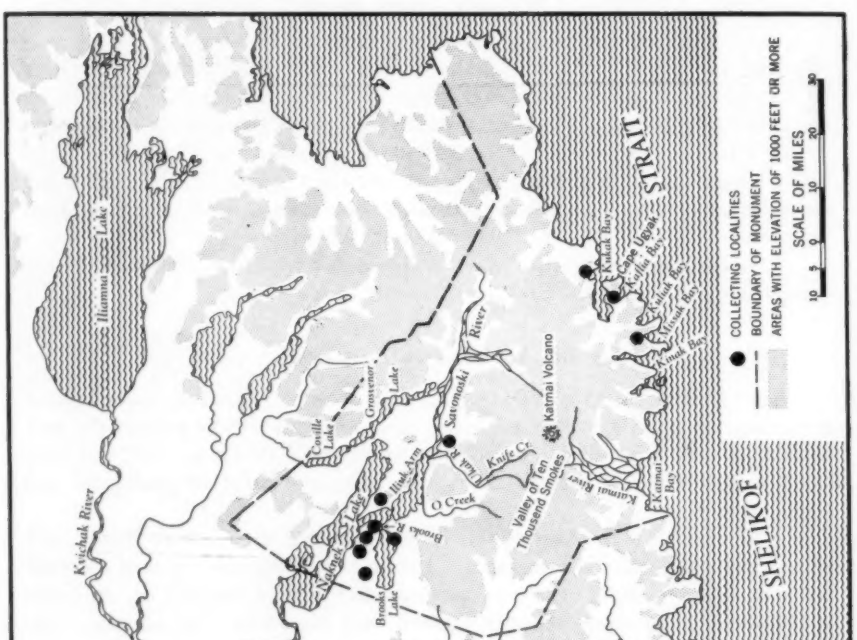

Fig. 1. Region of Katmai National Monument, Alaska.

Material and methods

Field work was performed by Schiller from July 1 to August 4, 1953 in the Katmai region, and from May 3 to May 23, 1954 in the region of Becharof Lake. Travel was mainly by boat and plane; in the monument a helicopter was sometimes used.

Mammals were collected by trapping and shooting; study skins were prepared in the field in the standard manner. All mammals were examined for the presence of parasites. Records of larger mammals were based on observations only, since none were collected. The skulls were prepared for study at the laboratory in Anchorage. The taxonomic work was performed by Rausch. The specimens collected will be deposited in the U.S. National Museum. Collecting localities are shown on the map (Fig. 1).

Results

Sixteen species of mammals were collected, and for 16 additional species sight records or information were obtained. These are discussed separately:

Sorex vagrans shumaginensis Merriam.* Dusky shrew.

Thirty-one specimens of this shrew were trapped at various localities: eleven near a small cove along the south side of Naknek Lake, in a marsh where *Calamagrostis* sp. was the predominant plant; four in a ravine at an altitude of about 2,000 feet north of Brooks Lake; four along the shore of Naknek Lake in a birch-alder community; twelve around the buildings of an abandoned cannery at Kukak Bay.

Osgood (1904) collected this shrew along Becharof Lake and at Kanatak. Although traps were set at both places in the spring of 1954 no specimens were taken.

Sorex cinereus hollisteri Jackson. Cinereus shrew.

Four specimens of *S. cinereus* were collected: two in a marsh at the east end of Naknek Lake, and two along the banks of a stream emptying into Iliuk Arm near the mouth of Savonoski River.

Osgood (1904) found this shrew to be scarce along his route across the Alaska Peninsula, but numerous in the coastal region.

Ursus arctos Linnaeus. Brown bear.

The brown bear was the mammal most in evidence in the monument. Bear trails were observed everywhere—in low grasslands, in dense alder thickets along river banks, and on snow fields in the mountains. During the time of the field work bears were numerous at lower altitudes (below 1,500 feet). Prior to the salmon run they were seen on the lower mountain slopes and along

*The specific name *S. vagrans* replaces *S. obscurus*, according to the recent revision by Findley (1955).

the river banks, where they were feeding on plants (particularly *Equisetum* sp.). After the salmon run began, the bears congregated along the streams, where they caught and ate salmon. None were seen around Kanatak and lower Becharof Lake, although tracks were noted across snow fields at higher elevations. Bears are hunted extensively outside the monument. A young female bear was killed by an Aleut hunter on May 13, 1954 on the beach at Wide Bay. This animal weighed 134 kg.

The bears of the upper peninsula are not typical of the very large *U. arctos gyas* Merriam, that occurs farther to the west. They average smaller in size, and cranially resemble more the animals to the north.

Vulpes vulpes alascensis Merriam. Red fox.

Red foxes were numerous in the monument and in the region to the southwest. They were abundant along the larger bays of Shelikof Strait. A den occupied by a family of foxes was found at the site of the former village of Kukak on Kukak Bay. It was inhabited by the adult male and female and six young. The foxes were feeding mostly on voles (*Microtus oeconomus*), and remains of recently killed animals of this species were scattered around the entrance of the den.

Foxes were common at Kanatak in May, 1954. Several dens were found in the sand drift on the northeast shore of Portage Bay. The animals were seen feeding at low tide along the beaches. An adult male weighing 6 kg. was collected here, and another adult male was found dead at Wide Bay.

Aleuts living in this area found several dead foxes after the snow melted in the spring of 1954. Descriptions of the behaviour of some animals they had seen in late winter indicated that they probably were rabid. During the month of March, one man killed four foxes close to his house and one of his dogs was bitten. In about two weeks the dog developed symptoms typical of rabies. The heads of the four foxes were sent to the laboratory in May, but decomposition was too far advanced to permit recovery of the virus. However, rabies virus was recovered from the brain of a fox killed at Naknek in April, 1954.

The foxes at Kukak Bay were found to harbour hookworms, *Uncinaria stenocephala* (Railliet, 1884), and tapeworms, *Taenia* sp.

Osgood (1904) reported that the Aleuts at Kanatak trapped more than 100 red foxes in the winter of 1902–3, mainly around the head of Becharof Lake.

Canis lupus Linnaeus. Wolf.

Although local pilots from both King Salmon and Egegik reported wolves to be fairly common in the monument, none were seen by any of the personnel of the Katmai project during the summer of 1953. Wolf tracks were found at the following localities: near the mouth of O Creek, along the Savonoski River, at Missak Bay, on the delta of Katmai River, and on the shores of Naknek Lake. The trail of one animal was also seen along Knife Creek in the Valley of Ten Thousand Smokes.

Osgood (1904) found no evidence of wolves in this region.

Martes americana actuosa (Osgood). Marten.

No marten or any evidence of them were noted in the course of this work. A pilot from Egegik reported seeing marten during the last few years in the vicinity of Coville and Grosvenor lakes. Mr. V. Cahalane (personal communication) also noted the occurrence of this species during a visit to the monument in the fall of 1940.

Osgood (1904) obtained no information on the occurrence of marten in this region.

Mustela erminea arctica (Merriam). Ermine.

One ermine was seen at the abandoned cannery at Kukak Bay by Dr. John Lucke, geomorphologist with the Katmai project. A field party reported the presence of another on one of the small islands in Kukak Bay on which glaucous-winged gulls were nesting. None were collected.

Osgood (1904) collected one ermine at the head of Becharof Lake, and secured other specimens from the general region.

Mustela rixosa eskimo (Stone). Least weasel.

An Aleut resident of Kanatak described what he believed were least weasels that he had observed around abandoned buildings in the village during the summer of 1953. At that time the population of voles (*Microtus* sp.) was at a high density. None were seen during the present work.

Mustela vison ingens (Osgood). Mink.

An adult female mink was captured alive at Kukak Bay and maintained for several days on a diet of voles. It later died, following the feeding of a small fish, and it was found that a bone had perforated its stomach. At the time of death the animal weighed 769 grammes and measured 548 mm. in total length.

According to Aleuts living at the head of Becharof Lake, mink are common in that region.

Lutra canadensis (Schreber). Otter.

Many trails of otter were found along small streams emptying into Naknek and Brooks lakes, and Iliuk Arm. Tracks were observed along lakes and streams near the coast of Shelikof Strait. According to the Aleuts, otter are common around Becharof and Ugashik lakes. No specimens were collected.

Osgood (1904) also found otter to be common around Becharof Lake.

Gulo gulo luscus (Linnaeus). Wolverine.

A wolverine was seen just north of Kukak Bay by Mr. William Thompson, geographer of the Katmai project. Schiller found tracks on the pass between Kanatak and Lake Ruth in 1954. The Aleuts were of the opinion that wolverines were relatively common in this area. No specimens were secured.

Osgood (1904) did not collect or observe wolverines in the region under consideration.

Felis lynx canadensis Kerr. Canada lynx.

Lynx were probably fairly common throughout the monument. These animals and their tracks were seen near the fish weir in Brooks River by personnel of the Katmai project. Tracks were observed on the banks of O Creek, and on the mud flats of Ukak and Savonoski rivers. No specimens were collected.

Osgood (1904) found the lynx rare during the time of his work.

Lepus americanus dalli Merriam. Snowshoe hare.

Snowshoe hares were scarce in all areas of the monument where observations were made in 1953. Old droppings were seen in nearly all timbered areas visited, but little recent sign was noted. The partially-eaten carcass of a young animal was found on a bear trail at the west end of Naknek Lake. No other specimens were obtained.

Lepus timidus othus Merriam. Arctic hare.

Pilots flying over the area reported seeing many arctic hares in the region of the Alaska Peninsula south of the coniferous forest in 1953-54, especially around Port Heiden, and Becharof and Ugashik lakes. In May, 1954 the hares were still in winter pelage and remained around snow fields at higher elevations. One female arctic hare weighing 5.5 kg. was collected near the lower end of Becharof Lake on May 16, and the partially eaten carcass of another was found at Wide Bay.

Osgood (1904) did not find any recent evidence of arctic hares during the time of his work.

Marmota marmota caligata (Eschscholtz). Hoary marmot.

Two small colonies of hoary marmots were found on a mountain at the northeast coast of Portage Bay. Two adults were collected there in the spring of 1954, one of which, taken on May 12, contained three embryos with crown-rump length of 60 mm. The skin of another marmot was obtained from an Aleut at Kanatak.

Osgood (1904) collected no marmots in this region, but mentioned specimens from Kanatak in the Biological Survey collections.

Citellus undulatus ablusus Osgood. Ground squirrel.

Ground squirrels occurred in a variety of habitats in the monument. Near the summit of the mountain rising from Cape Ugyak, Kukak Bay, their burrows had been excavated in deposits of loose, granular pumice. The entrances to these burrows were unusually large, probably because of the nature of the pumice. Twenty-three ground squirrels were collected. In addition, six adults were captured alive and brought to the laboratory in Anchorage, where two of the females gave birth to young. One litter, borne June 1, 1954, consisted of three animals weighing 6.6, 6.4, and 6.0 grammes. A second litter of two was born a few days later. None of the young survived more than a few hours.

Some of the ground squirrels collected in the monument harboured fleas, *Oropsylla idahoensis* (Baker). Ticks, *Ixodes angustus* Neumann, were found on ground squirrels from Cape Ugyak.

Osgood (1904) found this ground squirrel abundant.

Tamiasciurus hudsonicus kenaiensis Howell. Red squirrel.

Red squirrels were uncommon in the timbered regions north of the Aleutian Range, but the presence of old middens and nests was noted. Two female red squirrels were collected along Naknek Lake, one of which, obtained on July 8, 1953, contained one embryo (crown-rump length 30 mm.). Both squirrels harboured fleas; one was infested with *Monopsyllus vison* (Baker), and the other with *M. vison* and *Orchopeas caedens durus* (Jordan).

Osgood (1904) found red squirrels to be scarce in those places where he made observations.

Synaptomys borealis dalli Merriam. Bog lemming.

Two specimens of the bog lemming were collected during this study. One was trapped in a marsh near Brooks River; the other was taken at Cape Ugyak in an alpine habitat at an altitude of about 1,500 feet.

Osgood (1904) collected the bog lemming farther to the north, but did not observe any in the region under consideration. The present material extends the known range of this species to the southwest.

Dicrostonyx torquatus rubricatus (Richardson). Varying lemming.

On May 16, 1954 only one female varying lemming, weighing 40 grammes was collected in low, wet tundra along the southern arm of Becharof Lake. Another was seen on the pass between Portage Bay and Lake Ruth between two small fields of snow.

Although Osgood (1904) collected no varying lemmings, he stated: "A few small burrows, possibly of *Dicrostonyx*, were found in some sandy banks near the lower end of Becharof Lake, but excavation proved them deserted."

Clethrionomys rutilus dawsoni (Merriam). Red-backed vole.

Red-backed voles were uncommon in the monument north of the Aleutian Range during the summer of 1953; twelve animals were collected in this region. However, sixty animals were collected at Kukak Bay, where the population was dense, especially around abandoned cannery buildings. These voles were found in a variety of plant communities, including *Alnus-Equisetum*, *Picea-Alnus-Salix*, and *Calamagrostis*.

On the basis of a small series of specimens collected at Egegik River, near the outlet of Becharof Lake, Osgood (1904) suggested that a small peninsular form may exist in this region. Although the number available for study is small, nothing was observed that would support this view. This vole was abundant during the time of Osgood's observations.

Ticks, *Ixodes angustus*, were collected from one red-backed vole taken in the monument.

Microtus oeconomus kadiacensis (Merriam). Tundra vole.

North of the Aleutian Range the tundra vole was collected only at the site of the old Aleut village of Savonoski, near the mouth of the Savonoski River. Here seven voles were trapped in a *Calamagrostis-Elymus* community in a total of 1,440 trap nights. This vole was abundant along the coast of Shelikof Strait, however, and 294 were collected at Kukak Bay in late July, 1953. Deeply worn runways and other evidence indicated high densities of population at Kaflia, Kuliak, Kinak, and Missak bays.

In May 1954, when field work was undertaken at Kanatak and Becharof Lake, this vole had become scarce. Aleuts stated that the voles had been abundant in the fall of 1953, but apparently had died in great numbers during the winter. Numerous runways occurred from near sea level to an altitude of about 3,000 feet at Kanatak. More than 500 traps were set and maintained for 15 days, during which time only five voles were taken, and four of these were trapped around buildings in the village. Excavation of burrows at Kanatak disclosed carcasses of voles in nests, and dead animals were also found in vacant buildings. Members of the Katmai project who worked in the monument during the summer of 1954 reported few voles in areas where they had been numerous the year before.

As noted by Osgood (1904), *M. oeconomus* from near the base of the Alaska Peninsula is similar to *M. o. kadiacensis*, but the skull of the latter is somewhat more massive. Voles from the monument closely resemble specimens from the vicinity of Skwentna, farther to the north, and in colour were identical with topotype specimens from Kodiak Island.

Ectoparasites were collected from only a few voles at Kukak Bay; these included a tick, *Ixodes angustus*, and a flea, *Megabothris abantis* (Rothschild).

Microtus pennsylvanicus alcorni Baker. Meadow vole.

This vole was uncommon during the time of the present work. Three specimens were collected in small marshes along the south shore of Naknek Lake in about 4,000 trap nights. Runways were not seen.

Specimens of *M. pennsylvanicus* from the monument are identical with animals collected at Skwentna to the north. Although Osgood (1904) designated voles from this same general region as *M., pennsylvanicus drummondi* (Audubon and Bachman), the form occurring here has more recently been considered as *M. pennsylvanicus alcorni* (Baker, 1951) (*see* Hall and Cockrum, 1953). The present records extend the known range of this species to the southwest.

Zapus hudsonius alascensis Merriam. Jumping mouse.

Jumping mice were trapped in three different localities north of the Aleutian Range: one was taken above timberline at an elevation of about 2,000 feet; another was trapped in a marsh on the south shore of Naknek Lake; and four were collected on the mounds of the former Savonoski village. Three of the specimens from Savonoski had very sparse hair on the head and dorsum, but this appeared to be only an unusual molt.

Osgood (1904) recorded the jumping mouse from as far west as Cold Bay. The Aleuts of Kanatak and Becharof Lake knew nothing of the occurrence of this mammal.

Castor canadensis Kuhl. Beaver.

Beavers were abundant in the monument, particularly around Naknek Lake and in the Brooks River drainage. In the lowlands south of Brooks Lake, many beaver ponds were seen from a helicopter. One beaver dam near Brooks River was nearly a mile long. Beavers were also common in the lower Becharof Lake region. Several animals had been taken here by the Aleuts during the winter of 1953-54, and of these one skull was obtained. No other specimens were collected.

Osgood (1904) mentioned a small colony of beavers near Becharof Lake, and found the animals numerous also farther to the northwest.

Erethizon dorsatum myops Merriam. Porcupine.

No porcupines were seen in the area between Grosvenor Lake and the lower Savonoski River by any of the project personnel during the summer of 1953. On May 16, 1954 a female porcupine weighing 5.6 kg. was collected in a thicket of alder about 1,000 feet above Becharof Lake. According to the Aleuts, porcupines are not uncommon in this vicinity, and they are sometimes also seen at Kanatak.

Osgood (1904) obtained two porcupines from the Becharof Lake region and stated: ". . . . they have a great fondness for the aments and young leaves of the alder, which probably accounts for their occasional or possibly regular occurrence in the tundra region."

Ondatra zibethica spatulata (Osgood). Muskrat.

No muskrats were observed in the monument during the summer of 1953. The Aleuts find many muskrats in Becharof and Ugashik lakes, but only two were seen during the brief period of field work along the southern arm of Becharof Lake in May 1954. None were collected.

Osgood (1904) obtained eleven muskrats from Becharof Lake and found them abundant in suitable habitats throughout the region.

Alces alces gigas Miller. Moose.

Only a few moose were seen by personnel of the Katmai project in the summer of 1953. An adult male was found dead and nearly submerged in Naknek Lake. The molar teeth of this animal were excessively worn, apparently due to the abrasive effect of volcanic ash, which is present in quantity on the vegetation of the region.

The Aleuts reported seeing several moose around Kanatak, and some thought that the moose are ranging farther down the Alaska Peninsula than formerly. Maddren (*in* Osgood, 1904, p. 30) believed that the moose in this region were restricted in their distribution by the limits of birch forest. It is

now known that birch is not a requisite food species, and moose may be found wherever the larger species of *Salix* are abundant.

Several moose were seen during a flight from Kanatak to Naknek Air Base in May 1954. Most of these were south of Naknek Lake, in the area between Brooks Lake and Naknek River.

Rangifer tarandus ?granti Allen. Caribou.

Caribou were formerly found in large numbers in the region of Becharof and Ugashik lakes. Their distribution was continuous from the base of the peninsula, by way of the treeless area north of Naknek Lake, through the region of Lake Iliamna to the mainland. Residents of King Salmon stated that the caribou have been absent from the Naknek Lake area for many years and that none occur at the present time between Naknek Lake and Lake Iliamna. According to Leopold and Darling (1953), caribou discontinued their migration from the mainland to the peninsula when this range became depleted after intensive grazing by reindeer. The latter became originally established on the base of the peninsula about 1920; they numbered up to 10,000 or more animals and occupied the region of Dillingham-Egegik-Iliamna for more than 20 years. A small herd of caribou remained on the peninsula south of this region, and according to Scott *et al.* (1950) numbered about 2,500 animals in 1949. These animals winter on the tundra around Becharof Lake and pass the summer near the coast in the vicinity of Port Moller, 200 miles to the west. As shown by Leopold and Darling (1953), the gap in the distribution of these animals has not yet become closed again. However, since the lichens have recovered considerably on former reindeer range, Leopold and Darling predicted that the caribou may some day re-occupy this region.

It is unlikely that the subspecies *R. tarandus granti* has escaped crossbreeding with the introduced domesticated form. Osgood (1904) pointed out that the population of the peninsula was never separated from the mainland herds, as was thought by Allen (1902).

Phoca vitulina Linnaeus. Harbour seal.

Harbour seals were common along the coast of Shelikof Strait, particularly in Kukak, Katmai, and Portage bays. Many of these animals are killed annually by fishermen, who believe that they feed upon salmon. No specimens were collected.

Callorhinus ursinus (Linnaeus). Fur seal.

The carcass of a young male fur seal was found on the beach at Kanatak, where it had been washed ashore during May 1954. The animal had been dead for some time. The skull was preserved.

Eumetopias jubata (Schreber). Steller's sea lion.

The carcasses of two adult male Steller's sea lions were found on the beach at Kukak Bay in July 1953; both carcasses were badly decomposed.

Discussion

The effect of the volcanic eruption of 1912 on the mammals of the Katmai region cannot be evaluated. Detailed observations prior to 1912 are lacking, and it was unfortunately impossible to relate plant succession to presence and abundance of the various species of mammals. It is obvious that all of the smaller species, such as the microtine rodents and shrews, are widely distributed in this region, and no species which might be expected here is absent.

In the event of another eruption of similar magnitude, it is hoped that annual studies can be made on selected areas. This would make possible an evaluation of the initial effect upon the flora and fauna, and would permit an understanding of plant succession and the related occurrence of mammals.

Acknowledgments

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THE ROUGH-LEGGED HAWK IN THE AMERICAN ARCTIC

George Miksch Sutton* **and David F. Parmelee†**

THE rough-legged hawk (*Buteo lagopus*) has often been referred to as a "subarctic" or "Hudsonian Zone" bird. Peters (1931) did not mention any of the arctic islands in his statement concerning the breeding range of the New World race, *B. l. sanctijohannis*. Taverner (1935) stated that the northern limit of its range seemed "to just touch the southern edge of the arctic islands". Soper (1928; 1946) and Wynne-Edwards (1952) have given information concerning its breeding in southern Baffin Island. Sutton (1932) reported its breeding on Southampton Island, Porsild (1951) on Victoria and Banks islands, MacDonald (1954) on Prince Patrick Island. Apparently it does not range as far north in the eastern American Arctic as in the western. The map in Cade (1955) gives a good idea of its breeding distribution in the Canadian Arctic Archipelago. Oddly enough, it has never been found in Greenland (Salomonsen, 1950–1).

In southern Baffin Island *Buteo lagopus* is widely distributed today. The MacMillan expedition to the southwestern part of the island collected "one specimen and eggs" (Soper, 1928). Soper (*loc. cit.*) collected it at Cape Dorset and saw it at Amadjuak Bay. His recent comments (Soper, 1946) on the species are: "Breeds sparingly along the south coast from at least Lake Harbour to Foxe Channel. At present it is not known to occur elsewhere on the island." The northernmost record for Baffin Island is apparently that of Manning (*in* Bray, 1943), who saw one at Taverner Bay, along the west coast just north of the Arctic Circle, on June 8, 1940. This record Soper (1946) apparently overlooked.

Wynne-Edwards was the first to report the species from southeastern Baffin Island. He found it at York Sound, Frobisher Bay and Frobisher air base.

Nestings in Frobisher Bay, Baffin Island, in 1953

In 1953 at least four pairs of rough-legs nested near the head of Frobisher Bay. We did not observe the species about Silliman's Fossil Mount, 16 miles west of the air base, and we did not see it in the Wordie Bay area, or near Cape Dorchester, or along the southeastern shore of Amadjuak Lake. All these places lack noticeable cliffs.

The rough-leg had started nesting well before we reached Frobisher Bay. We first saw it on June 17. On the 19th we located a pair about a mile northwest of the air base. Both birds were black, marked with gray, buff, and white, especially on the underwings. They must have been moulting, for

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there were feathers, large and small, all over the place. Bent (1937) states that the annual moult is completed "between April and November". Besides feathers we found numerous droppings, several tufts of lemming fur, and two half-eaten collared lemmings (*Dicrostonyx groenlandicus*). The hawks screamed and dived at us and twice we saw one strike a snowy owl (*Nyctea scandiaca*) a staggering blow in mid-air.

We found their nest (nest 1) on June 21. It was about 20 feet below the top of a cliff, on a slight projection. We could look directly down at the six shiny, not very heavily marked eggs. The nest was neatly and deeply cupped. In its walls were dead willow branches and roots a foot or more long. The lining was of moss and lichens to which clung small feathers and bits of down. While we were near the nest a large falcon, probably a female peregrine (*Falco peregrinus*), flew swiftly past, not far overhead. The rough-legs did not dive at this intruder.

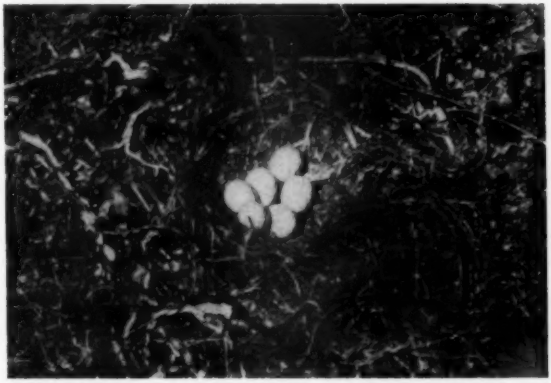

Fig. 1. Nest of rough-legged hawk on cliff. Near head of Frobisher Bay, Baffin Island. June 21, 1953.

We went to the nest for photographs on June 23. The old birds started screaming when we were fully a quarter of a mile away, but they did not dive at us until we had climbed to the promontory directly above the nest. None of the six eggs was pipped as far as we could tell. Three days later, we approached the eyrie from above and took the birds by surprise. Creeping to the very brink of the cliff, we looked down on the incubating female. She had not heard us and was gazing across the valley. Suddenly the male screamed, and the female, without a glance in our direction, dropped from the nest. The nest now contained only five eggs. Presently the female too was screaming, in a voice higher than her mate's.

The eggs all hatched some time between June 26 and July 3. On this last date we visited the nest twice. In the morning we had an unforgettable look at the female feeding four of her brood (one was asleep). Bits of lemming held in the tip of her beak the chicks sought eagerly. Size variation within the brood indicated a protracted hatching period. The chicks were

buffy or creamy white, not grey, and one of the larger seemed to be more strongly buffy on the crown and back than the others. On our afternoon visit the three larger chicks were sitting up, biting at one another with surprising ferocity.

On July 7, along the eastern side of Tarr Inlet, some miles east of nest 1, a rather small, very dark rough-leg flew toward us screaming. This was the male of the Tarr Inlet pair. On July 11 we visited nest 1, finding the parents and five young all in good condition. The only remains of prey visible in and around the nest were those of lemmings.

A week later we found nest 2 on Hill Island. The hawks, circling above the eyrie, squealed as the motorboat approached, but they did not fly toward us. The nest, a hundred feet or more above water level, was on a narrow ledge well below the top of the cliff. The two good-sized young, both in normal light phase plumage, were standing. The parents were dark and blotchy, like all the other adults we had seen. We did not visit this nest again.

On July 22 the two rough-legs screamed at us along the east shore of Tarr Inlet. The first to fly toward us was the dark male referred to above. The less aggressive female was thin-voiced by comparison. Her plumage looked faded and worn, though she was also decidedly melanistic. The nest (nest 3) was a slight affair of moss, roots, and heather on a steep, rocky slope about a quarter of a mile from highwater mark. We could climb to within twenty feet from below, and from above could let ourselves down to a big rock and look directly across at the four well developed chicks, all of which were in normal light phase plumage.

At nest 3, on July 27, we observed the tactics of the aggressive male. When we were fully half a mile away he appeared, circling high above the nest. Soon he began to squeal and to circle toward us, staying high. His dives were shallow, so the roaring of his wings was faint. The female we did not see until we were within 50 yards of the eyrie. She slipped in from the east, coasted along the slope above us, and screamed shrilly. On July 28 we photographed this nest (see Fig. 2). The young, with mouths open, were probably panting, for the day was the warmest we had had, with a maximum of 59°F.

On August 3, two miles to the northeast of nest 3, we heard squealing from another pair of dark, blotchy rough-legs. Parmelee found the remains of two old nests, then investigated an east-facing, 200-foot cliff above which the hawks were circling and screaming. The female had a way of alighting momentarily on a high knob before attacking in a series of shallow dives. The following day Parmelee climbed the talus below the cliff and saw a fringe of sticks protruding from a ledge just above him. On peering over he was almost struck in the face by a young hawk as it sprang forward and flew off. The remaining three young made no attempt to fly. The nest was a mere handful of twigs and roots. Of the four nests it had been the hardest to find, yet it was the only one accessible without a rope. All four young birds were normal light phase.

Fig. 2.
Nest of rough-legged hawk on huge rock. Tarr Inlet, near head of Frobisher Bay, Baffin Island. July 28, 1953.

By this time we had become so accustomed to melanistic adult rough-legs that we wondered whether breeding individuals of this region ever wore normal light phase plumage. Since most of the rough-legs we had seen in winter in the United States had been non-melanistic, the thought crossed our minds that the normal light phase was actually the first winter plumage, that birds in first winter plumage were rarely, if ever, melanistic, and that adult birds were rarely, if ever, normal light phase. See also Cade's (1955) comments on melanism.

Our last visit to nest 1 was memorable. Three of the five young were flying strongly about the cliff and two were still in the nest. The youngest was now at least 38 days old. Since we wanted a full-fledged young as a specimen, we decided to take one of the two left in the nest. Both squealed shrilly as we dropped bits of moss on them. Suddenly the larger sprang off, flew with astonishing speed across the valley, and alighted clumsily. We caught and banded it. The nestling collected (male, GMS 11824) was solid black on the belly; its chest, flags, and under tail coverts were brownish buff; its chest was heavily, its flags lightly streaked with dusky. Tufts of creamy white down clung to the plumage of the chin, upper throat, malar region, and tarsi.

Food

So far as we were able to ascertain, the rough-legs were feeding exclusively on lemmings. Both the collared lemming and brown lemming (*Lemmus trimucronatus*) were common in all the places we visited regularly. The abundance of lemmings, plus a scarcity of competitors such as foxes (*Alopex lagopus*) and weasels (*Mustela erminea*), plus the artificial, ample food supply for ravens (*Corvus corax*) at the dump of the air base may have been partly responsible for the local abundance of the rough-legged hawks, snowy owls, and peregrine falcons. Authors agree that the rough-leg is a confirmed eater of small rodents. Blair (1936) found that numerous pellets of rough-legs in Norway were "composed entirely of the fur and bones of voles".

Nesting success at Frobisher Bay

Each of the four breeding pairs observed by us was more or less successful. From nest 1 one egg disappeared, but the remaining five hatched and four young fledged. Nest 2 may well have held more than two eggs. The two young that we could see probably had passed the most critical stage of their nestlinghood. At nest 3 the four young were large when we last saw them, and all probably fledged. At nest 4 one bird fledged, three others very likely did, and one or more others may have done so before we discovered the nest. We observed no slow wasting away of smaller, weaker young (Blair, 1936).

Relationship with the peregrine

Nowhere did we find the rough-leg and peregrine nesting at all close together. Two peregrines that nested on a small cliff near the mouth of the Sylvia Grinnell River were collected on June 18. This cliff was about a mile from rough-leg nest 1. Along the channel between Hill and Bishop islands, where we found rough-leg nest 2, we saw one peregrine, but not its eyrie. At Silliman's Fossil Mount peregrines nested, but we never saw a rough-leg there. At two other places did we record the peregrine, but not the rough-leg.

Possible extension of range

What we have reported above appears at first glance to indicate that the rough-leg is becoming commoner in the American Arctic and that it is extending its breeding range. We must bear in mind, however, that in the greater part of the Canadian Arctic Archipelago very few bird observations have been made, and that no one has studied a given island year after year for a long period or worked the long coast lines in an attempt to plot the breeding distribution of the rough-leg, peregrine, and gyrfalcon (*Falco rusticolus*). Four or more pairs of rough-legs may, for all we know, have bred near the head of Frobisher Bay for a long time.

Ahlmann (1953) states that arctic climate has fluctuated considerably and that in some areas the mean annual temperature has risen significantly in recent

decades. The records for Nottingham and Resolution islands (both near Frobisher Bay) indicate an increase of approximately 1°F. (Longley, 1954). Slight amelioration of climate would not, of course, suddenly produce more cliffs on which rough-legs might nest, and it probably would not eliminate periods of lemming scarcity. All we can say at present is: (1) the rough-leg was not a rare bird at the head of Frobisher Bay in the summer of 1953; (2) lemmings were common there that summer; (3) the northern limits of the breeding of the rough-leg in the New World are well north of the North American mainland.

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REVIEWS

THE CLIMATE OF CENTRAL CANADA.

By W. G. Kendrew and B. W. Currie. *Ottawa: Queen's Printer, 1955. 9¾ x 6½ inches; ix + 194 pages; 5 plates, numerous charts, diagrams and tables. $1.00.*

Some time ago a series of research monographs on the climate of certain Canadian regions was prepared in various Canadian universities. These studies were originally commissioned by the Defence Research Board, under funds administered by the Department of Transport. The reports—five in all—were considered too detailed for publication, and the Department of Transport set about the preparation of condensed and revised versions.

The present volume, based in part on one of these studies (by B. W. Currie), is the first revision to be published. It is the work of W. G. Kendrew, the well-known British climatologist, who has not only revised Currie's original study that originally covered only the Mackenzie Basin and Keewatin, but has extended it to include also the Prairie Provinces. There is a general introduction, and this is followed by a detailed description of the screen-level climate of a series of arbitrarily defined climatic regions. Extensive tabulations of climatological averages, including station tables, make the book very useful for reference purposes.

The choice of climatic parameters is traditional and unventuresome. The reduction of temperature to mean sea-level on the monthly maps is hard to defend, since in the north the temperature lapse rate of the lower atmosphere is normally inverted in the cooler months; reduction to a standard pressure surface, such as 1,000 or 900 mb., might have obviated this difficulty. There is some disagreement between the other maps and those recently published in the *Climatological Atlas of Canada*, issued by the same Department. Nevertheless the book fills a real need, and will be welcome to all who travel in the northwest. One hopes for early publication of the remaining volumes.

There are some editorial slips, of which photograph 2, p. 96, is the best example. The view shown is of a locality on the upper Thelon River, above Beverly Lake, not Wager Bay, as the legend indicates.

F. Kenneth Hare

MAMMALS OF NORTHERN ALASKA ON THE ARCTIC SLOPE.

By James W. Bee and E. Raymond Hall. *Lawrence, Kansas: Allen Press, 1956. (Museum of Natural History, University of Kansas, Misc. Publ. No. 8). 9 x 6 inches; 309 pages; col. frontispiece; 4 plates, 127 numbered figures, 5 tables. Cloth $4.00, paper bound $1.00.*

This book represents the first attempt to provide a definite account of the mammals occurring on the Arctic Slope of Alaska. It is based on specimens collected and observations made by the authors and their assistants during two summers (July 3-September 6, 1951; June 14-September 12, 1952), and on material in the collections of nine museums in the United States and Canada.

A coloured frontispiece by R. P. Grossenheider depicts the five species of microtine rodents and the three species of shrews considered in the book. Although well executed by the artist, the subtle shades of colour seen in the living animal are not accurately portrayed. The book consists of a short introduction, a check list of the species considered, a discussion of these mammals, a hypothetical list of species for which records are lacking, a key to the mammals of the Arctic

Slope, a short discussion (22 pages) of the geography, climate, and biotic communities of the Arctic Slope, an itinerary, and a bibliography of 177 titles.

The introduction contains a discussion of the cyclic fluctuations of certain species of arctic mammals, a phenomenon attributed to the effects of starvation, predation, and disease. There is also a brief comparison of the faunas of arctic, temperate, and tropical regions.

The bulk of the book, 247 pages, is taken up by the discussion of the 42 species of mammals recorded. In addition to the scientific names, the common and Eskimo names are given. A list of pertinent references precedes each species account. A detailed description of each species is given, supplemented by appropriate illustrations, including a line drawing of the skull. Under "remarks" are given field observations and data on trapping results, reproduction, molt, and general ecology. Previously published records of occurrence are summarized at the close of each account, and stations of occurrence are shown on an outline map.

Emphasis is placed on the shrews and microtine rodents, with over half the total section on species being devoted to them. For these mammals detailed observations on reproduction, composition of populations, and molt are given. Many data are presented by means of graphs, the use of which in some cases might be considered excessive. The discussions of mammals do not adequately take into consideration the fluctuations in population density so characteristic of shrews and mouse-like rodents of the region. Consequently, observations on habitat preferences and interspecific relationships are often misleading. Everywhere in the discussions one finds animal behaviour interpreted in a purposeful way, such as (page 81): "The lemmings retreat to these ice chambers . . . to keep cool during the hottest part of the summer." Throughout the book other observations are often given interpretations not supported by available data. The authors use their own data almost exclusively and make no attempt to synthesize the work of others in interpreting their observations. Had this been done, a much more valuable contribution would have resulted.

Not many specimens of the larger mammals were collected, nor were specimens in other collections studied, especially of the larger carnivores (wolf, bear, wolverine, etc.), but this is also true in the case of the common seals, specimens of which are obtainable in the coastal Eskimo villages. It is unfortunate that the authors did not discuss the taxonomic status of the terrestrial carnivores, even where it appears to be important. In some accounts skulls that were not collected in Alaska have been used for illustrative purposes, among others black bear and otter from California, moose from Minnesota, and caribou from Greenland. Although this is of little technical importance, it nevertheless distracts from the value of the work. In all such cases the same subspecies that occur on the Arctic Slope are found also in the forested regions to the south, and suitable material is available. Of the 29 terrestrial species considered at least 24 are widely distributed in the forested regions of Alaska and northern Canada.

In the section on caribou the authors forcefully criticize the "control" of wolves on the Arctic Slope as being biologically unsound and probably detrimental to the welfare of the herds.

The localities where the authors made their collections were largely places where collections had been made by others. However, although mammals have been studied from relatively few localities, the region is so uniform that few differences can be expected.

The authors have made the fullest use of the material at their disposal. The book will serve as an important and valuable guide to those continuing this work in arctic Alaska.

ROBERT L. RAUSCH

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NORTHERN NEWS

Superficial geology of the Firth River archaeological site, Yukon Territory

Aided by a research grant from the Banting Fund provided through the Arctic Institute, J. R. Mackay and W. H. Mathews were able to spend the period from August 18 to September 3, 1956 at the Firth River archaeological site under excavation by Dr. R. S. MacNeish (*Arctic*, Vol. 8, 1955, p. 195) and his party. Close and helpful collaboration was maintained with MacNeish during the visit. Seventeen days were spent studying geomorphic and stratigraphic problems associated with the archaeological site and with the nearby terrain. Approximately 1,000 linear feet of pit walls were examined in order to relate the archaeological complexes to the stratigraphic succession. In addition, 161 test pits were dug at strategic points (over 150 of these were excavated to the permafrost table that varied from about 17 to 48 inches below the surface) for

the purpose of extending the stratigraphic data beyond the areas under excavation by the archaeological party. Several traverses were made to areas within a day's walk from the camp-site. Observations were made during the flights to and from Firth River on geomorphic features of the arctic coastal plain. On the return flight, a brief stop was made at Herschel Island in order to compare its soils with those of the Firth River area to the south.

As has been pointed out by MacNeish ("The Engigstciak Site on the Yukon arctic coast", *Anthropological Papers of the University of Alaska*, Vol. 4, 1956, pp. 91-111), the stratigraphy of the site is complicated. Some of the factors making interpretation difficult are:—

1. A shallow active layer that limited the depth of excavations and hence the depth of the sections available for study.
2. Duplication within the original sequence of clay, sand, and muck members.
3. Extensive solifluction, slumping, and frost heaving that have disturbed the original sequence in many areas.
4. Possible inversion of topographic slope by growth of ground ice causing a reversal in the direction of solifluction and slumping.
5. A geographical position on the borderline between glaciated and unglaciated areas.

Added to these difficulties were poor weather and the rapid collapse and filling with water of many of the freshly excavated pits. However, a fair measure of success was achieved in establishing the stratigraphic position of the older archaeological complexes and in estimating subsequent disturbances by geomorphic processes. The relationship of the stratigraphic succession to a late glacial advance westward along the coastal plain was determined. Minimum figures for the extent of marine submergence, apparently associated with this advance, were obtained.

Specimens of clay were collected in collaboration with Dr. MacNeish for further study. Carbon 14 datings, to be obtained from Dr. MacNeish's specimens, will aid in estimating rates of geomorphic processes in this arctic environment and may help to relate the late glacial advance in this area to those that occurred elsewhere. When the study is completed, a full report of the superficial geology and its relationships to the archaeological complexes will be prepared in collaboration with Dr. MacNeish.

J. R. MACKAY and W. H. MATHEWS

Studies on the flora and vegetation of the taiga zone of northern Manitoba

The investigations were confined to a small upland area (at 59°03′N 96°47′W), which lies about ten miles northwest of the western tip of Great Island, on Seal River. Excellent camping facilities were provided by Mr. E. Kronlund, a local trapper and prospector. His camp is situated on a small, unnamed lake about ten miles due north of the junction of Big Spruce and Seal rivers. Transportation from Churchill, Man. to this camp was provided by Transair; the direct flight by Norsemen aircraft on June 30 lasted 70 minutes. The entire period in the field was spent at Kronlund's camp, which was most conveniently located for the purpose of the investigation. Field work was completed on August 2 and the return flight to Churchill was made on August 4.

The area of the investigation lies within the Precambrian Shield region of Manitoba, and the greater part of the land surface consists of low hills of glacial till; occasional outcrops of bedrock are present. A large esker passes through the area in an approximately north-south direction. Many shallow basins are filled with peat deposits of considerable depth, which bear a tundra vegetation and show soil polygons.

Comprehensive collections of vascular plants, mosses, and lichens were made. Because of the absence of basic rocks in the substratum, which are present in the Hudson Bay Lowlands a short distance to the east, the area yielded only about 150, mainly subarctic, species of vascular plants. The collections include a number

of additions to the flora of Manitoba and several range extensions of previously recorded species.

Travel was by powered canoe and on foot, the latter being greatly facilitated by the proximity of the large esker mentioned above. Detailed descriptive accounts and quantitative analyses were compiled for the various vegetation types encountered, and various edaphic studies were made. The area is of great phytogeographical and ecological interest. It lies just at the transition between continuous forest and forest tundra, and some progress was made toward an elucidation of the factors that limit the extension of forest into the tundra on upland sites.

There are divers patterns of vegetation that are associated with particular features of surface geology. In regions undisturbed by fires the predominant coarse till substratum of the area bears a black spruce (*Picea mariana*) forest, with the ground cover dominated by lichens and various ericoid shrubs. Many of these well drained habitats are occupied by subseral types, among which larch (*Larix laricina*)—in distinct contrast to its behaviour in southern areas—plays an important rôle as the dominant after fire. White spruce (*Picea glauca*) is the dominant tree of the esker, forming open stands on stable areas. Elsewhere on the esker an intricate pattern of degeneration and pioneer vegetation units is common. Certain exposed slopes have a close cover of lichen-heath vegetation; in large depressions various aquatic, marsh and bog communities are present. The nature of the vegetation on the flanks of the esker is often largely controlled by the type of community that occupies the adjacent terrain. Along the banks of the Big Spruce River a local fringe forest of white spruce is present, in which trees of considerable stature occur. Many tree height and trunk diameter data, as well as increment cores were collected from species in all community and habitat types. Just above the junction with Seal River, the course of Big Spruce is marked by a pattern of terraces and oxbows, with which various interesting plant communities are associated.

The formulation of general conclusions, both phytogeographical and ecological, must await the complete analysis and collation of data. The work was made possible through a grant from the Banting Fund provided through the Arctic Institute. J. C. RITCHIE

A field and laboratory study of the ecology, life history and behaviour of ptarmigan in Alaska

The objects of the project in 1956 were to acquaint the investigator with ptarmigan habits and habitats, and to begin the compilation and analysis of data relating to specific aspects of their breeding biology. The work was supported by a grant from the Banting Fund received through the Arctic Institute and began with the search for a suitable study area on May 1. Reconnaissance was hampered by deep snow and the relative scarcity of ptarmigan. The most promising location was Eagle Summit, 105 miles northeast of Fairbanks, Alaska, adjacent to the Steese Highway, and field work began there on May 17.

The study area consists of 20 square miles of high, rolling hills, mainly above timberline that lies here at about 3,000 feet elevation. The narrow valley bottoms contain scattered stands of spruce and willow; the slopes and hill tops are covered by tundra. The vegetation of the tundra is not homogeneous, but decreases in density and number of species with increasing altitude.

A census taken immediately after arrival showed approximately 30 pairs of rock ptarmigan (*Lagopus mutus*) and three of willow ptarmigan (*Lagopus lagopus*). Courtship, pairing and mating had commenced at that time, and by the second half of May most of the birds had started incubating. During May and June four nests from 1954, 14 from 1955, and nine from 1956 were found; eight of the nests of the current season belonged to rock ptarmigan. The average clutch of this species contained six eggs; the single willow ptarmigan clutch had

nine. The peak of hatching occurred between June 10 and 20, after an incubation period of approximately 21 days.

During July and August the behaviour, movements, and cover preferences of broods were studied. A total of 26 rock ptarmigan broods and three willow ptarmigan broods were observed in July. By the middle of that month all young ptarmigan were able to fly.

Several specimens collected during the season were examined for crop contents and parasites, and duplicate blood smears were taken from 18 birds. The analysis of this material will be completed during the winter of 1956-7.

Predation appeared to be of minor importance during this investigation. In the three summer months only nine freshly killed ptarmigan were found. However, the remains of 87 ptarmigan were discoverd, the great majority of which had been killed during the previous winter or early spring. This indicates considerable mortality among wintering populations, and presents an interesting problem for future research.

During this work the investigator enjoyed the help of many persons interested in the project. It would be impossible to mention here the names of all those who were of assistance during the summer, but I am very grateful to several scientists at the Arctic Health Research Center, Anchorage, Alaska, to personnel of the U.S. Fish and Wildlife Service, and to residents of the Berry Mining Camp at Eagle Creek, Alaska. Dr. John Buckley, leader of the Alaska Cooperative Wildlife Research Unit, was especially generous in providing transportation, supplies, and special equipment, in addition to giving valuable advice on several phases of the work and making available the facilities of the Unit.

ROBERT B. WEEDEN

Geomorphological and glaciological investigations in the Torngat Mountains of northern Labrador

The writer and his wife, Pauline, left Montreal by air for Goose Bay, Labrador on July 2, 1956 and from there travelled by Beaver aircraft to Northwest River, where they enjoyed the generous hospitality of the British Newfoundland Corporation. The departure from Montreal had been delayed for two weeks on account of the unusually late break-up in the Eastern Arctic. Further delay was unavoidable as a reconnaissance flight to Nain showed that the northern lakes and fiords were still ice-bound on July 5.

In order to make the fullest possible use of the time during the delay the party was flown to a lake south of Makkovik on the Labrador coast and worked there on the local glacial geomorphology until July 26. The party reached the Torngat Mountains finally on July 27, and even at that late date many of the inland lakes were frozen, so that only two food and fuel caches could be established. Base camp was set up on a sand spit on the south side of Upper Kangalaksiorvik Lake, inland from Seven Islands Bay. One cache was placed on Lower Komaktorvik Lake, twenty miles to the south, and the second on an inland lake at an altitude of about 1,000 feet, a few miles west of the Labrador-Quebec boundary.

Two major field excursions were made, each of about two weeks' duration. The first used the cache on the inland lake about sixteen miles west of the base camp and penetrated to the head of Abloviak Fiord on the Ungava Bay side of the Labrador Peninsula. Short excursions were made along the way through the Torngat Mountains, which here exceed 4,000 feet. The land to the west of the mountains was examined from a camp near the head of Abloviak Fiord.

The second major excursion was centred on a camp at the head of Lower Komaktorvik Lake. It involved work in the mountains north of this lake and between it and Nachvak Fiord to the south. In this area the higher summits are more than 5,000 feet above sea level. The final two weeks were spent working from the base camp.

Despite the very short season and much bad weather most of the originally planned work was accomplished and 13

of the main summits were climbed in an attempt to assess the degree of glaciation that the mountains have suffered and the stages by which the final ice cover disappeared. The conclusion has been reached that at the height of the glaciation even the highest summits were deeply submerged by continental ice flowing toward the Atlantic Ocean. It has also been discovered that the rôle of the Torngat "local" glaciations in the main glaciations of eastern North America was very slight. Contrary to a current theory that these mountains have been one of the "source" areas and areas of final dispersal of the continental ice masses, it appears that tongues of the continental ice sheet continued to flow through the great west-east troughs of the Torngats after the mountain valleys had become free of local ice and only cirque glaciers remained. There is also evidence that at least two major glaciations occurred in this area.

Routine observations were made on the geology, geomorphology, snow line, and remnant cirque glaciers. This material, together with the main work on the glaciation of the Torngat Mountains, will be published at a later date.

The Beaver aircraft landed at the base camp on Sept. 17 and the party arrived at Northwest River the same day and finally reached Ottawa. This work was made possible by a grant from the Banting Fund provided through the Arctic Institute, a McGill University-Arctic Institute Carnegie Scholarship, and the provision of air transport by the British Newfoundland Corporation. J. D. Ives

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